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Volume I

EVALUATION AND HANDBOOK DATA OF 7050 RIVETS

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Lockheed-Georgia Company

A Division of Lockheed Corporation

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Rivet	Corrosion Compatibility	Heat Treatment
Solid	Stress Corrosion	Specifications
Aluminum	Fatigue	NAS 1097
Shear Strength	Joint Allowables	MS 20426
Elevated Temperature	7050-T73	MS 20470

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The aluminum alloy 7050 wire has been represented by Alcoa as a high strength, easily upsetable and corrosion compatible rivet material. Rivets made from this alloy and heat treated to the overaged T73 temper, indicate a high shear strength. Fsu = 43 Ksi (driven condition). The rivets were also found to be corrosion compatible and with no stress corrosion failure in the alloy wire when subjected to a stress equal to 75% of yield strength (Fty = 63 Ksi) for 30 days in salt solution. The joint fatigue data compared favorably with that

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of 2024-T31DD (ice box) rivet in both low load and medium load transfer configuration tests. The shear strength of 7050-T73 rivet was also compared to the 2219-T81 rivet at elevated temperatures 250 and 350°F and 16, 96, 288 hour soak. It was determined that the 7050 rivet can replace the 2219 rivet in the temperature environment. The maximum reduction of room temperature strength was realized at the 350°F and 288 hour soak test conditions. This reduction was 42% for 7050-T73 rivet as compared 34% for 2219-T81 rivet. The joints static allowable strength were computed from the joint test data using the MIL-STD-1312 test configuration and criteria and MIL-HDBK-5 guidelines for joint allowable data analysis and presentation.

Standard rivet configuration conforming to NAS 1097, MS20426 and MS20470 were evaluated in the program.

FOREWORD

This technical report is submitted by the Lockheed-Georgia Company, Marietta, Georgia, under contract F33615-79-C-5030, "Evaluation and Handbook Data of 7050 Rivets," with the Air Force Wright Aeronautical Laboratories, Materials Laboratory, System Support Division, Wright-Patterson Air Force Base, Ohio. Mr. Robert Urzi, AFWL/MLSA, was the Air Force Manager for this program.

This program was conducted with the Engineering Branch of the Lockheed-Georgia Company, Marietta, Georgia under the direction of Chief Engineer - Research and Technology, Mr. L. W. Lassiter. The program manager was E. J. Bateh of the Advance Structures Department. The experimental work was performed by H. S. Pearson.

The author wishes to express his thanks to Mr. John Aurentz of the Briles Rivet Company for his assistance during the course of the work.

This work was performed under Project No. 62102F, "Metallic Structural Materials," Task No. 24180111.

Data contained in this report shall not be used in any way for promotion or advertising purposes.

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SECTION I. INTRODUCTION

Mechanical fastening of aircraft structure is an important and costly factor in the manufacture of aircraft. The continuing research for improvement in the performance of mechanically fastened joints has largely stemmed from the need for increased fatigue life and durability in current airframe designs. The airframe fastener industry in the last two decades has presented some novel and useful methods in this area. However, all these concepts were costly, required a high-quality hole associated with precision tools, and an elaborate quality control and inspection technique to accomplish the objective of fastener installation with the needed reliability and confidence.

The aluminum riveting system has been the most extensive method used to join various assemblies by the aircraft industry. Its uniqueness as to cost, minimum training requirements, utilization of simple inexpensive tooling, and adaptability to automation make it ideal for mechanical joining. However, use of the system has been limited to thin sheet structure and low design stress areas. Attempts to adapt the high-strength 7000 series aluminum alloys into rivet fasteners have been unsucessful. The wire form of this series of alloys has failed under the extensive squeeze pressure required to obtain the needed installation parameters.

The recent development of the 7050 aluminum alloy has renewed interest in a 7000 series alloy rivet and an extensive program was initiated by the U. S. Air Force to explore this concept. The program was successful in proving the feasibility of using the 7050 alloy wire as rivet material (Reference 1). This limited study and qualification testing of the 7050 rivet established the basis for the current program.

The objectives of this program were (1) to advance the 7050 riveting technology to production status, and (2) to compare newly acquired 7050 rivet data with other rivet materials currently used. In order to accomplish this goal, all parameters needed by the designer and manfacturing engineer were experimentally and analytically characterized. Sufficient data were generated to establish the static strength properties of this rivet. Design allowables were established according to the guidelines of Chapter 9 of MIL-HDBK-5, "Metallic Materials and Elements For Aerospace

Vehicle Structure." Material heat-treat response for both 7050 rivet wire and rivet was finalized, and rivet upset parameters and shear strength were experimentally determined and analyzed. The effects of thermal and corrosive environments were fully investigated by appropriate exposure. Comparison was made of the static, fatigue and environmental properties of the 7050-T73 rivet to the 2024-T3 (ice-box) rivet. The thermal properties of 7050-T73 rivets were compared with those of 2219-T81 rivets.

The experimental and analytical procedures used in this program were performed according to applicable Military Standards and Guidlines.

SECTION II. SCOPE

2.1 EXPERIMENTAL PROGRAM

The scope of the experimental program was to resolve or establish:

- Mechanical properties of 7050 aluminum alloy rivets and rivet wire
- Joint design allowables for a number of 7050-T73 rivet configurations
- Elevated-temperature shear strength properties of 7050-T73 and 2219-T3 rivets
- Fatigue behavior of riveted joints utilizing 7050-T73 and 2024-T3 rivets

Discussions of each of the above parameters are presented in the subsequent sections of this report.

2.1.1 Mechanical Properties Tests of 7050 Rivets and Rivet Wire

The mechanical properties test program for rivets and rivet wire was divided into a number of segements: heat-treatment process verification, tensile and upsetability test, final heat-treatment specification, and single and double shear strength. The heat-treatment process verification, which was derived from tests performed in Reference 1, was modified initially in the solution-treatment part of the heat-treat cycle. The solution temperature of 900 ($\pm$5)$^{\circ}$F for 15 ($\pm$1.0) minutes was changed to 900° ($\pm$5)$^{\circ}$F for 30 ($\pm$15) minutes, and finally changed to 890 ($\pm$10)$^{\circ}$F for 30 ($\pm$15) minutes. Rivets heat-treated to the initial and revised solution condition were bucked and squeezed to bucked tail diameters and heights of 1.4-1.5d and 0.3d, respectively, where "d" is the measured diameter of the rivet or wire. The final mechanical properties were based on a final heat-treat of 890 ($\pm$10)$^{\circ}$F for 30 ($\pm$15) minutes, followed by a first-step aging of 250 ($\pm$5)$^{\circ}$F for four (4) hours and second step aging of 360 ($\pm$2)$^{\circ}$F or 350 (+2,-0)$^{\circ}$F for 8 hours with natural cool down to room temperature. Half of the rivets and rivet wire were tested at 360°F second step aging temperature and the other half at 350°F second step aging temperature. The tests were performed according to the applicable Military Standards.

Stress Corrosion and corrosion tests were also done. Stress corrosion consisted of the application of a tensile load to the rivet wire specimen. The load was selected as a percent of the yield strength of the wire material and was applied for 90 days. The corrosion test was applied to aluminum panels having three different finishes. 7050 and 2024 rivets were installed in these panels and exposed to a corrosive environment.

2.1.2 Joint Design Allowables

The joint allowables tests were performed utilizing three 7050 rivet configurations (NAS1097, MS20426 and MS20470) installed in two aluminum alloy (2024-T3 and 7075-T6 clad) sheet materials. The number of joint specimens tested along with joint sheet material thicknesses used are detailed in Table 1. The joint specimen configurations were in accordance to MIL-STD-1312, Test 4A. Undriven double shear strength and single-shear driven strength of the 7050 rivets were accomplished according to MIL-STD-1312 tests No. 13 and 20. The appropriate rivet hole sizes were drilled according to Table 8.1.2.(a) of MIL-HDBK-5C. The upset head dimensions were 1.4 - 1.5d diametrically and 0.3d high. These dimensions were taken from Lockheed Standard Process Specifications. The wire materials were mainly procured from the Briles Rivet Company and the finished rivet shapes were fabricated by Blake Rivet, South Gate, California and subsequently heat treated to T73 temper by Brilles Rivet Company, Santa Ana, California.

2.1.3 Elevated Temperature Tests

The scope of the elevated temperature tests, detailed in Table 2, consisted of the two test temperatures and three soak times. Driven rivet, single-shear tests according to MIL-STD-1312, test 20, were used to define the high-temperature shear strength. An equal number of 2219-T81 rivets were also used in the test to establish comparative data, since alloy 2219 is assumed to be a temperature-resistant aluminum alloy.

TABLE 1. MATRIX FOR JOINT STATIC TESTS

RIVET DIAMETER	1/8		5/32		3/16		1/4		TOTAL NUMBER OF SPECIMENS
HOLE DIA.	0.1285		0.159		0.191		0.257		
RIVET CONFIG.	MS	NAS	MS	NAS	MS	NAS	MS	NAS	
SHEET THICKEN IN.									
.025		3							3
.032	3*	3		3					9
.040	3		3	3		3			12
.050	3	5	3					3	14
.063	3*				5	3		5	16
.071	3	3	3	3	5		3		20
.080	3	3	3	3		3	5	3*	23
.100	3*	3			5		3	3*	17
.125			3	3	5	3	5	3	22
.160					5	6	3	3*	17
.190							3	3	6
TOTAL	21	20	15	15	25	18	22	23	159

ALL THE ABOVE COUNTERSUNK SPECIMENS WERE TESTED IN 7075 & 2024 ALUMINUM ALLOY SHEET AT ROOM TEMPERATURE

TOTAL SPECIMENS = 2 X 159 = 318

THE SPECIMENS WITH ASTERISK WERE RUN FOR PROTRUDING HEAD MS20470 IN 7075 & 2024 ALUMINUM ALLOY SHEET AT ROOM TEMPERATURE

TOTAL SPECIMEN = 2(18) = 36

MS STANDS FOR MS 20426 RIVET CONFIGURATION
NAS STANDS FOR NAS 1097 RIVET CONFIGURATION

2.1.4 Fatigue Tests of Riveted Joints

The fatigue tests are outlined in Table III for the two aluminum alloy rivets: 7050-T73 and 2024-T3. The tests were performed at a number of stress levels to generate a well defined S - N curve. The stress levels were selected to give life cycles between 10^4 to 10^7 cycles. Two types of specimen configuration were used in order to simulate both low load transfer and medium load transfer joints found in conventional airframe structures.

2.2 ANALYTICAL PROGRAM

The purpose of the analytical program was to present appropriate analysis procedures that are recognized and used in the analysis of the type of data resulting from this program. The strength data incorporated a statistical analysis to establish a minimum statistical allowable with associated confidence and exceedance. The joint-allowables program was analyzed according to the requirements of the Guidlines - Chapter 9 MIL-HDBK-5C.

TABLE 2. ELEVATED TEMPERATURE TESTS

RIVET DIAMETER IN.	SOAK & TEST TEMPERATURE °F	SOAK TIME HOURS	NO. OF SPECIMENS PER VARIABLE	UPSET METHOD	RIVET MATRL	TOTAL NO. OF SPECIMENS
3/16	250 & 350	16, 96, 288	6	H, M	2219-T81 & 7050-T73	144
3/16	RT	0	6	H, M		12
1/4	250 & 350	16, 96, 288	6	H, M		144
1/4	RT	0	6	H, M		12
1/4	*	16, 96, 288	6	H, M		36

* HEATED TO 350 F AND SOAKED FOR 16, 96, AND 288 HOURS THEN TEST AT ROOM TEMPERATURE

** SPECIMENS WERE EQUALLY DIVIDED BETWEEN HAND BUCKED (H) AND MACHINE SQUEEZED (M)

TABLE 3. JOINT FATIGUE TESTS - NUMBER OF TEST SPECIMENS

RIVET	LOW LOAD TRANSFER △1	MEDIUM LOAD TRANSFER △2	JOINT MATERIAL	TOTAL
7050-T73	16	15	2	62
2024-T3 (DD)	15	15	2	60

NOTES:

RIVET CONFIGURATION WAS MS 20426
JOINT MATERIAL THICKNESS WAS .125 INCH
JOINT MATERIAL WAS 7075 & 2024 ALUMINUM ALLOY
1/2 OF THE JOINT SPECIMENS WERE HAND BUCKED RIVETS
1/2 OF THE JOINT SPECIMENS WERE MACHINE SQUEEZED RIVETS
△1 SPECIMEN DETAIL DRAWING IS GIVEN IN FIGURE 7
△2 SPECIMEN DETAIL DRAWING IS GIVEN IN FIGURE 8

SECTION III. EXPERIMENTAL PROGRAM

3.1 RIVET AND WIRE MATERIAL

The rivets and wire materials were procured in conformity to the specification and chemistry of 7050 aluminum alloy. Since no wire specifications were available, the 7050 wire had to be bought from a rivet producer, Briles Rivet Company, and to their own material specification. That specification is included in Appendix A. Currently, Amendment 3 to Specification QQ-A-430 does include 7050 rod/wire.

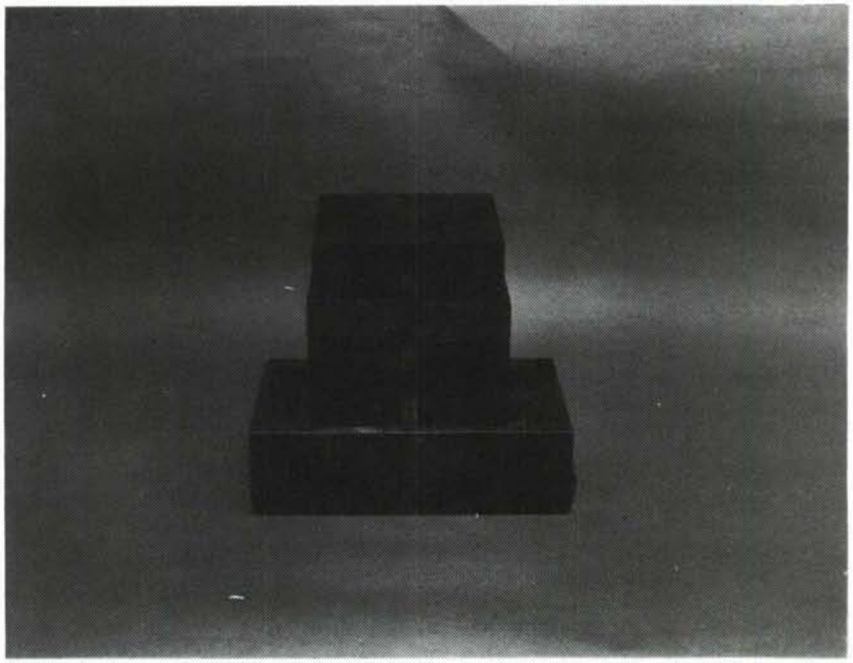
3.2 HEAT-TREAT RESPONSE

During the early phase of the program tests were performed to define and establish the final heat-treat. Two lots of material, Alcoa Lots No. 097021 and No. 097041, were procured in the H-13 condition as wire and rivets (3/16 inch and 1/8 inch in diameter), respectively. The wire and rivets from each lot were subjected to the following heat-treatments:

A - Solution-treated at 900 ($\pm$5)^{o}F for 15 ($\pm$1.0) minutes
B - Solution-treated at 900 ($\pm$10)^{o}F for 30 ($\pm$15) minutes

Double shear tests by MIL-STD-1312 test 13 and Figure 1 were performed on eight specimens from each diameter and heat-treat. Upsetability tests, by both squeezing and bucking, were also performed on rivets and wire from the two lots and heat-treat. The results of the heat-treat response established a heat-treatment with a change in the solution temperature and time. This heat-treatment process, presented in Appendix B, was used throughout the test program. In brief, the treatment was to:

Solution-treat at 890 ($\pm$10)^{o}F for 30 ($\pm$15) minutes
1st stage age at 250 ($\pm$5)^{o}F for 4 hours
2nd stage age at 355 ($\pm$5)^{o}F for 10($\pm$) 2 hours



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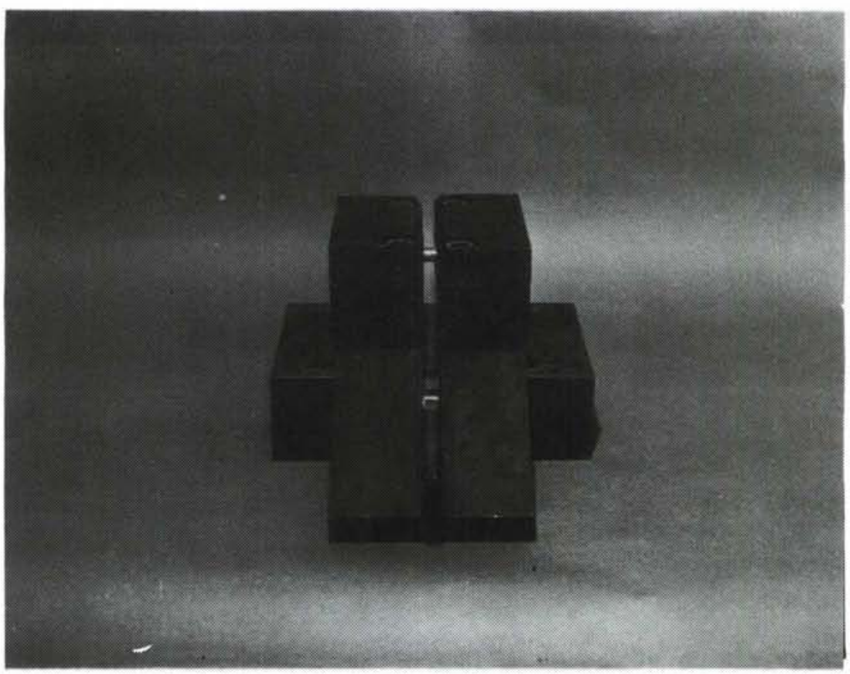


GUILLOTINE WITH BLADE REMOVED TO SHOW RIVET

Figure 1. Double Shear Test Fixture

3.3 MECHANICAL PROPERTIES

The mechanical property tests were run for both rivets and rivet wire. The rivet wire mechanical property tests consisted of single shear and tensile tests. The rivets were tested in single shear in the driven condition and the double shear in the undriven condition. Stress corrosion tests were also run on the rivet wire and corrosion compatibility on the driven rivets. The individual tests and the test procedures are detailed below.

3.3.1 Double Shear Strength

The double-shear tests were applied to 96 rivets and 96 wire specimens. The specimens were for 8 diameters, ranging from 1/8 through 3/8 in 1/32 inch increments. One-half of the specimens were aged at the second stage at 360 $(+0,-2)^{o}$ and the other half at 350 $(+2,-0)^{o}$. All tests were conducted in a 50,000-pound-capacity Baldwing-Lima-Hamilton Universal testing machine S/N SR4-6. Appropriate load ranges were used for each rivet diameter and type of test. The testing machine was calibrated in accordance with MIL-C-45662A. Accuracy of all ranges is $\pm$0.50% of indicated load or $\pm$0.10% of range.

The test fixture, generally in accordance with Figure 1 of MIL-STD-1312 Test 13, was available for use as shown in Figure 1. The fixture consisted of a blade and a base, which was fitted with removable cylindrical specimen holders containing holes for inserting the rivet or wire, as shown in Figure 2. The test specimen (either a rivet with head removed or a piece of wire) was inserted into the holders such that a gap of one diameter existed between the two holders and one-half of the remaining length was in each holder. The blade was inserted in the two specimen holders and the assembly tightened so that no gap existed between the specimen holders and the blade insert. The assembly was then centered under the compression fixture of the testing machine. Load was applied at a rate as specified in MIL-STD-1312 Test 13 for the specific rivet or wire diameter being tested to ultimate load. Complete separation was not obtained in all cases, although shearing on both sides of the blades was a criterion for test validity.

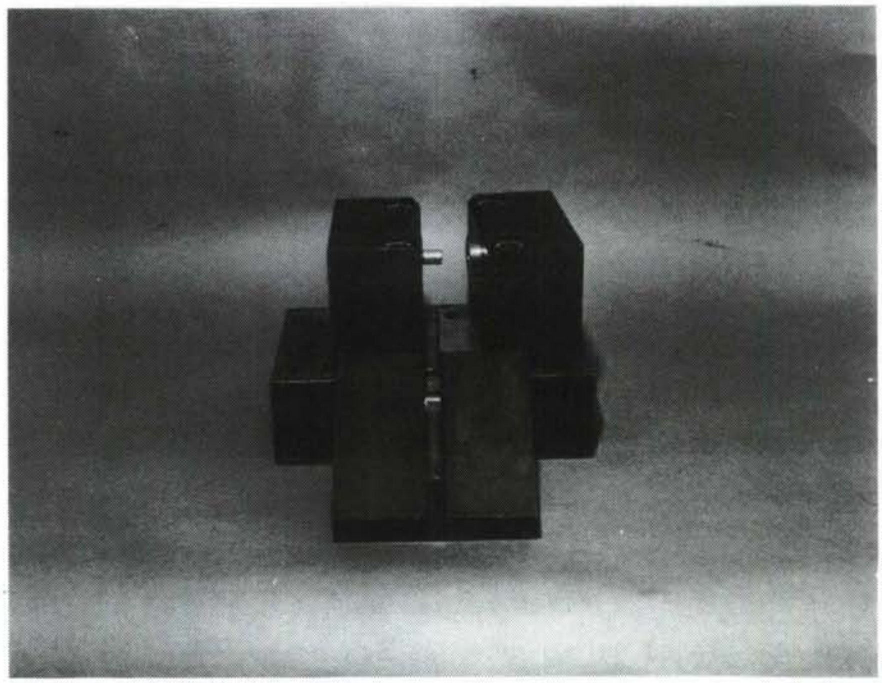


Figure 2. Double Shear Jig with Right Specimen Holder Moved to Right and Cylindrical Specimen Holder Pushed Partially Out

3.3.2 Single Shear Strength

Single shear test were performed on 136 rivet specimens. The rivets were universal head, MS20470. Eight rivet diameters, ranging from 1/8 inch to 3/8 inch inch in 1/32 inch increments were used in this test. The rivets were then heat-treated to the second stage aging temperature of 360 (+0,-2)^{o}F or 350 (+2,-0)^{o}F. Fifty-two rivets were installed in the fixture by hand bucking (HB) and 84 by machine squeezing (MS). The rivets were driven by aircraft mechanics skilled in rivet installation procedures. The hand bucking was done with rivet gun and bucking bars. The rivet squeezing procedure used either an automatic rivet machine or a hydraulic press. The criterion used for correctly bucked or squeezed rivet was the measurement of the buck tail diameter to a minimum 1.4d and a height of 0.3d minimum, where d is the actual rivet diameter. All bucked tails were inspected to ensure that cracks were not present to influence the test results.

The test jig shown in Figure 3 and the shear blade in Figure 4 were fabricated in accordance with MIL-STD-1312 Test 20. The specimen (two shear blades) were put into the jig, and the wing nuts were turned finger-tight to eliminate cocking of the specimen. The jig was then centered under the compressive fixture in the testing machine. Load was applied at a rate as specified in Test 20 for each rivet diameter tested until failure. The failed rivet halves were tapped out of the blades and retained, and the blades were reused as necessary.

3.3.3 Tensile Test Of Wire

Tensile tests were performed on four wire diameters: 1/8, 1/4, 5/16, and 3/8 inch. All of the wire specimens were subjected to the two heat-treat conditions A and B, which were previously discussed. The wires were slightly bowed after heat treatment, and no attempt was made to straighten them. The tensile specimens all standard 2.0 inch gage-length tensile coupons, were installed in a 30 KIP capacity Riehle Universal Testing Machine. The load ranges were 1500 pounds for the 1/8 inch diameter wire and 6000 for the other diameters. The specimens were loaded through

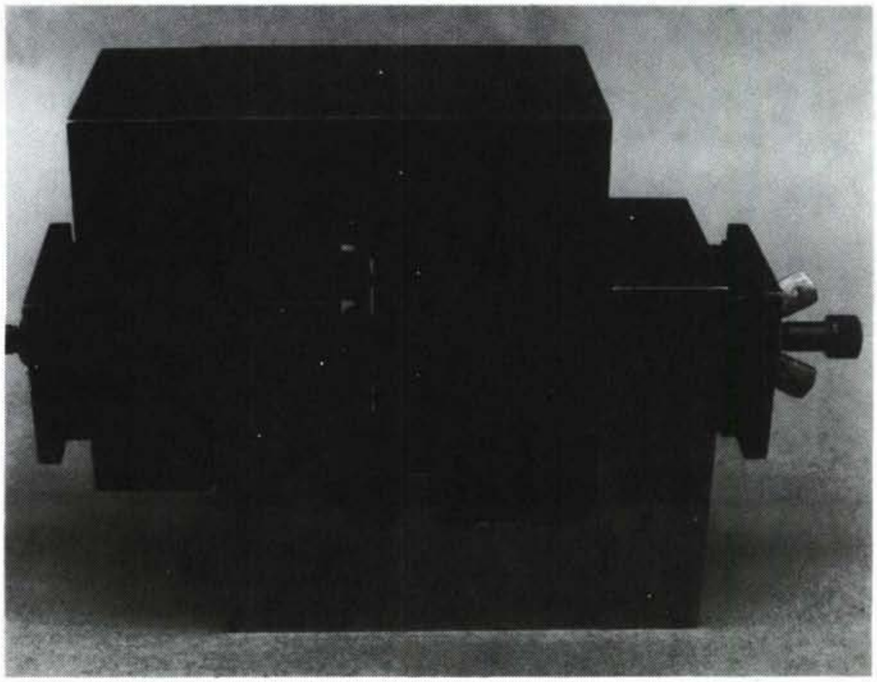
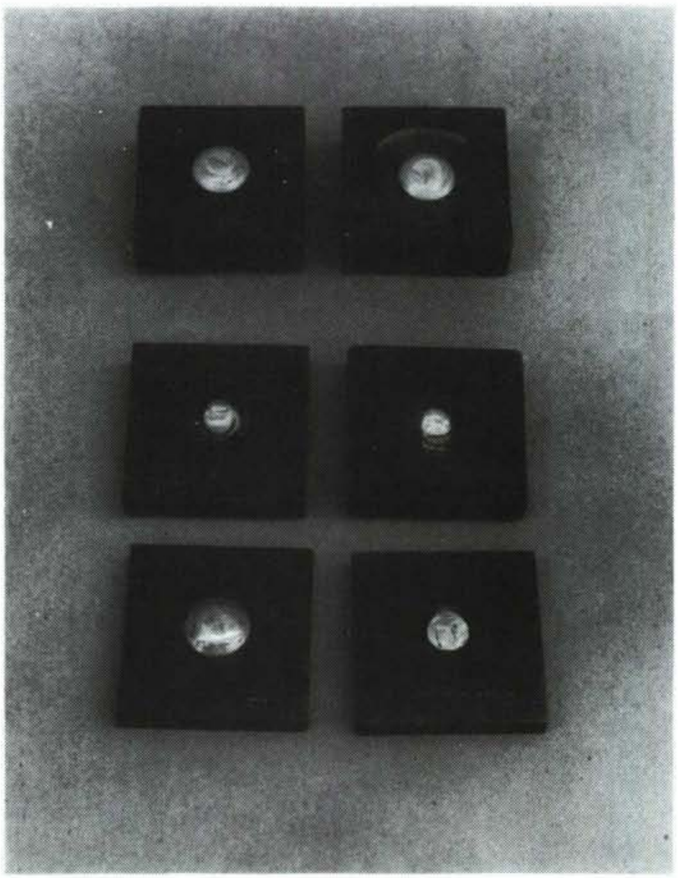


Figure 3. Single Shear Test Jig



BEFORE TEST

AFTER TEST

Figure 4. Shear Blades for Single Shear Test Jig

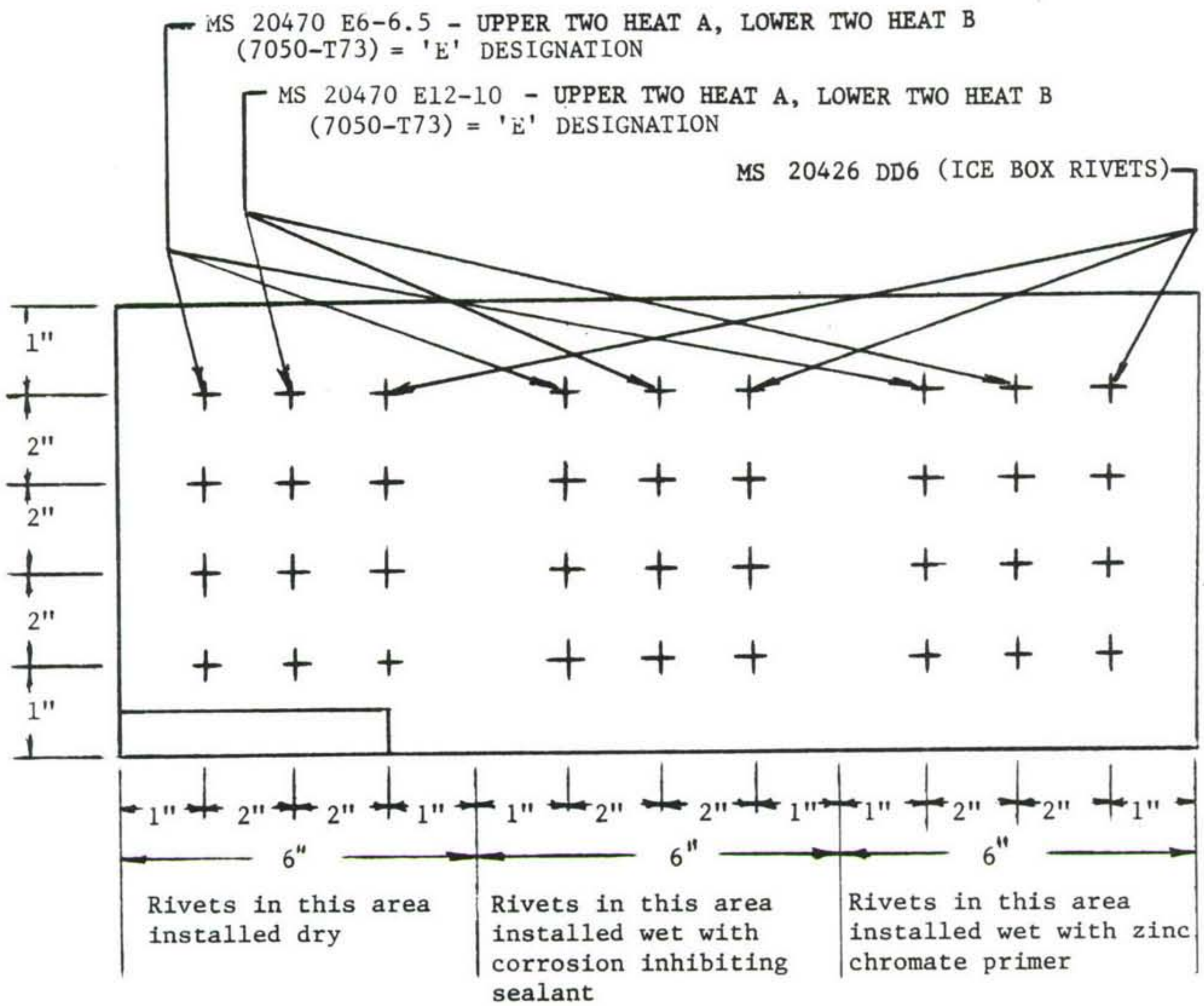
spherically seated Templin grips (V grips for 1/4 inch wire and above, and flat grips for the 1/8 inch diameter wire), using 150-grit emery cloth on wire ends, at a strain rate of 0.005 inch per inch until the 0.2 percent offset was reached. The load deformation curves were recorded autographically with an SR4.

3.3.4 Corrosion Test

Corrosion tests consisted of corrosion test panels and stress corrosion of wire specimens, as described in detail below.

Corrosion panels - Six 18 by 8-inch corrosion panels were prepared. Three of the panels were made from bare 0.250-inch-thick 2024-T3 aluminum alloy sheet, and three panels were made from bare 0.190-inch-thick 7075-T73 aluminum alloy sheet. All panels were made to the geometry shown in Figure 5. One panel of each material was drilled and assembled with no surface treatment, one panel of each material was sulfuric-acid-anodized, and one panel of each material was treated per MIL-C-5541 conversion coating (alodine) and then drilled and assembled. Each of the panels was divided into three sections. Rivets were installed dry in section one, wet with corrosion-inhibiting sealant in section two, and wet with zinc-chromate primer in section three. Each section contained four 3/16-inch diameter 7050-T73 rivets, four 3/16-inch diameter 2024-T31, DD, ice-box rivets, and four 3/8-inch diameter 7050-T73 rivets. In each row, the outside rivets were hand-bucked and the inner rivets were machine-squeezed. All panels were exposed to 5 percent salt spray per FED-STD 141 in a cabinet for ninety days.

Stress Corrosion of Wire - A standard 1.0-inch gage length round tensile specimen were made per ASTM E8 from 3/8-inch diameter 7050-T73 rivet wire heat-treated to the A and B heat-treat conditions, and two heats of 7050 material. Two specimens representing each heat and heat treatment were tested in tension in the SR4-6 Universal testing machine, to determine the 75% yield value required for the test. The extensometer was calibrated to ASTM Class C traceable to NBS. Ten specimen from each heat and heat treatment were loaded to 75% of determined yield stress. Four unloaded specimens of each heat and heat-treat were used for control. All



NOTES 1. Note that the MS20426 DD6 rivets are countersunk; the others are pan head.

2. The 3/8 dia. rivets are to be machine squeezed. The upper and lower 3/16 rivets are to be hand bucked; the center two are to be machine squeezed.

3. Rivets driven to minimum 1.4 x rivet diameters and 0.3 x rivet diameter high.

4. Rivet holes are to be reamed to conform to within ± .005 of the following table.

Rivet Size	3/16	3/8
Drill No.	11	W
Nominal Hole Dia., In.	0.191	0.386

Figure 5. CORROSION PANELS

specimen were subjected to alternate immersion in 3.5 percent salt solution for 30 days.

3.4 DESIGN ALLOWABLES

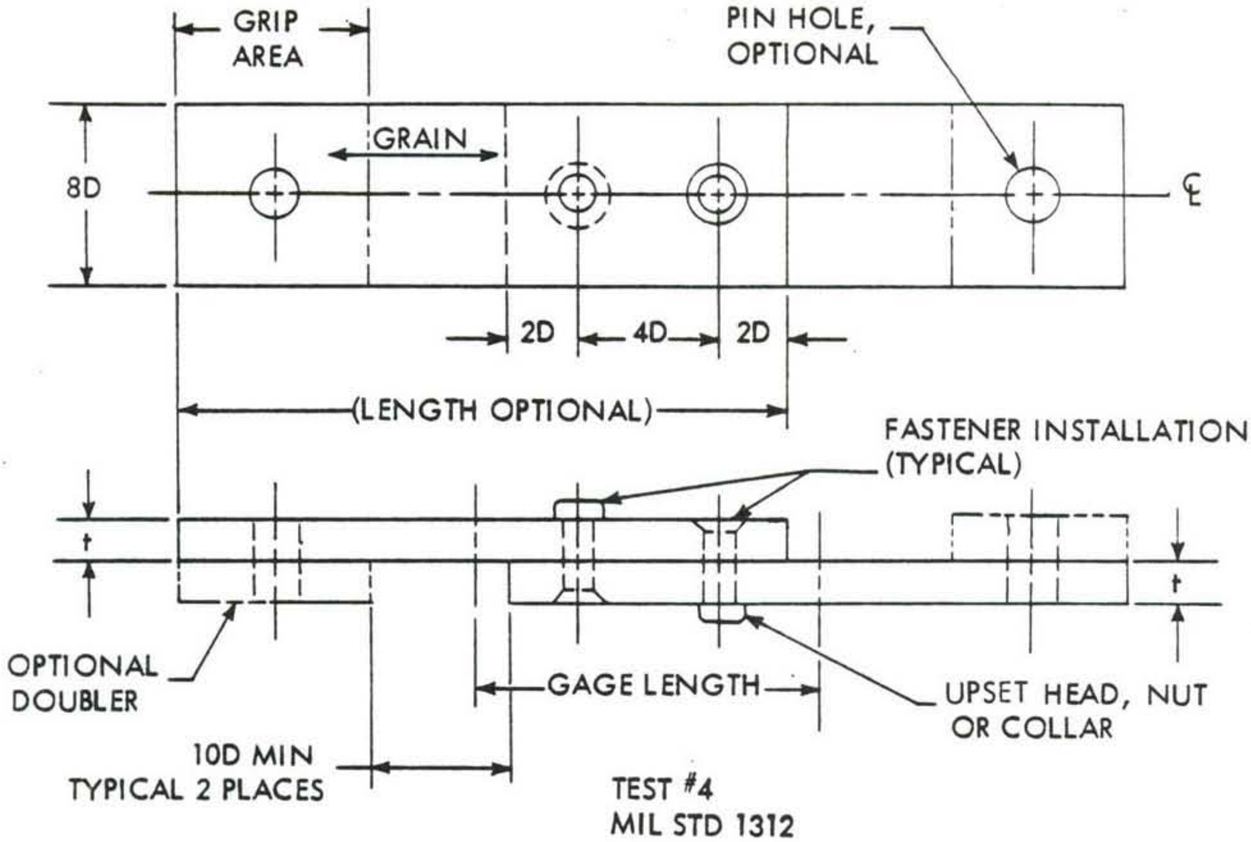
Design allowables for the 7050-T73 rivet were divided into two areas: The static joint strength with 7050-T73 rivet and the shear strength of the driven rivets. The tests used for each of the areas are discussed below.

3.4.1 Joint Static Strength

The static strength tests of riveted lap-joints were conducted according to the requirements of MIL-HDBK-5C, Chapter 9, paragraph 9.4, "Properties of Joints and Structures," and MIL-STD-1312, Test 4A, using the preferred configuration as shown in Figure 6. The rivets used in these test were 100° flat countersunk head (MS20426 & NAS1097) and universal head (MS20470). Four diameters in the countersunk configuration (1/8-, 5/32-, 3/16-, and 1/4-inch) and two diameters in the universal head (1/8- and 1/4-inch) were used in this test. All the rivets were heat-treated to the production heat treat, which specifies a 2nd-stage aging of 355 ($\pm$5)$^{\circ}$F. The rivets were procured from the Blake Rivet Co. and heat-treated by the Briles Rivet Co. in accordance with the heat-treat specification in Appendix "B."

Sheet materials used for this program were 2024-T3 clad aluminum alloy and 7075-T6 clad aluminum alloy in 11 gages. All material was used in the as-received condition, with no surface preparation except cleaning. Tensile tests were performed on all gages of both materials on the SR4-6 Universal Testing Machine, using an Class C extensometer. The tests were in the longitudinal direction.

Four drill jigs were fabricated, one for each rivet size, to ensure that all specimens were drilled within the required tolerances and hole sizes as specified in Table 8.1.2(a) of MIL-HDBK-5C. After drilling, samples were removed from the jig and the holes countersunk as necessary, using a standard drill press. All fastener holes were deburred at the faying surface and on the exit side.



NOTES:

1. Fastener holes shall be line drilled perpendicular to sheet surface within 1°. Hole drill sizes shall be as listed in table below. Holes are to be reamed to within ± 0.005 of the listed nominal size. All holes to be deburred at the faying surface and at the exit side. When countersinking is required, the countersink shall be concentric with the hole within 0.002 TIR and the depth shall be such that the installed fastener is flush within +0.002 inch - 0.005 inch. Tolerance on edge margin = ± 0.010; spacing and width = ± 0.030.

Rivet Size, Inch.	1/8	5/32	3/16	1/4
Drill No.	30	21	11	F
Nominal Hole Dia., In.	0.1285	0.159	0.191	0.257
Fillet Radius At Head	0.011	0.014	0.018	0.026

Material Thicknesses as noted in Tables 4 thru 7

Figure 6. Lap Joint Specimen Configuration

A total of 328 specimens were fabricated. The dimensions of the specimens and the matrix of variables are given in Figure 6 and Tables 4 through 7.

Seventy-five percent of these specimens (245) were tested at the Lockheed-Georgia Company and 25 percent (83 specimens) were tested at the Applied Technical Services, Inc., Atlanta, Georgia.

All tests at Lockheed-Georgia Company were conducted in a 50,000-pound capacity Baldwin-Lima-Hamilton Universal Testing Machine, S/N SR4-1. At Applied Technical Services all tests were performed on a 60,000-pound capacity Baldwin-Lima-Hamilton Universal Testing Machine, S/N 523104. In both cases, appropriate load ranges were used for each rivet diameter. At both facilities, a Baldwin SR4 extensometer and a SR4-to-microformer converter were used to record strain. Load rate was 100,000 pounds per minute per square inch of fastener shear area. Yield loads were determined using the secondary modulus method and an offset at yield equal to 4 percent of the nominal rivet hole diameter. (Nominal rivet hole diameter is that diameter defined in MIL-HDBK-5C paragraph 9.4.1.2, and Table 8.1.2(a), for solid rivets.)

The Universal Testing machines and extensometers were calibrated traceable to NBS in accordance with MIL-C-45662A and company procedures. Universal Testing machines are calibrated at one-year intervals and extensometers at 6-month intervals. The Lockheed-Georgia universal testing machine is accurate to $\pm 0.5\%$ of indicated load or $\pm 0.1\%$ of range, whichever is greater. The ATS universal testing machine is accurate to $\pm 1\%$ of indicated load or $\pm 0.1\%$ of range, whichever is greater. In both cases, the extensometer is accurate to ASTM class B2.

3.4.2 Rivet Shear Strength

A total of 120 single-shear driven rivet tests were performed as part of the allowables program. The driven single-shear tests were obtained from three lots of material per heat-treat and 15 total specimens per diameter and per rivet configuration. The rivets were heat-treated in the same manner as rivets discussed above. The single-shear driven tests were performed according to MIL-STD-1312, Test 20 and the test procedure discussed Section 3.3.2.

TABLE 4. 1/8 DIAMETER RIVET SPECIMENS

SHEET NO.	SHEET MATERIAL	SHEET THICK (t) (IN.)	RIVET STYLE	RIVET DASH NO. (1/16")	TYPE RIVET HEAD	NO. OF SPEC. REQ'D.	ASSIGNED SPECIMEN NUMBER
13	7075	0.025	NAS 1097	-4	FLUSH	3	J1, J2, J3
32	7075	0.032	NAS 1097	-4	FLUSH	3	J4, J5, J6
10	7075	0.050	NAS 1097	-4.5	FLUSH	5	J7, J8, J9, J10, J11
11	7075	0.071	NAS 1097	-5.5	FLUSH	3	J12, J13, J14
15	7075	0.080	NAS 1097	-5.5	FLUSH	3	J15, J16, J17
7	7075	0.100	NAS 1097	-6	FLUSH	3	J18, J19, J20
22	2024	0.025	NAS 1097	-4	FLUSH	3	J21, J22, J23
21	2024	0.032	NAS 1097	-4	FLUSH	3	J24, J25, J26
20	2024	0.050	NAS 1097	-4.5	FLUSH	5	J25, J28, J29, J30, J31
24	2024	0.071	NAS 1097	-5.5	FLUSH	3	J32, J33, J34
23	2024	0.080	NAS 1097	-5.5	FLUSH	3	J35, J36, J37
26	2024	0.100	NAS 1097	-6	FLUSH	3	J38, J39, J40
32	7075	0.032	MS 20426	-4	FLUSH	3	J41, J42, J43
12	7075	0.040	MS 20426	-4.5	FLUSH	3	J44, J45, J46
10	7075	0.050	MS 20426	-4.5	FLUSH	3	J47, J48, J49
33	7075	0.063	MS 20426	-5	FLUSH	3	J50, J51, J52
11	7075	0.071	MS 20426	-5	FLUSH	3	J53, J54, J55
15	7075	0.080	MS 20426	-5.5	FLUSH	3	J56, J57, J58
7	7075	0.100	MS 20426	-6	FLUSH	3	J59, J60, J61
21	2024	0.032	MS 20426	-4	FLUSH	3	J62, J63, J64
19	2024	0.040	MS 20426	-4.5	FLUSH	3	J65, J66, J67
20	2024	0.050	MS 20426	-4.5	FLUSH	3	J68, J69, J70
30	2024	0.063	MS 20426	-5	FLUSH	3	J71, J72, J73
24	2024	0.071	MS 20426	-5	FLUSH	3	J74, J75, J76
23	2024	0.080	MS 20426	-5.5	FLUSH	3	J77, J78, J79
26	2024	0.100	MS 20426	-6	FLUSH	3	J80, J81, J82
32	7075	0.032	MS 20470	-4	PAN	3	J83, J84, J85
33	7075	0.063	MS 20470	-5	PAN	3	J86, J87, J88
7	7075	0.100	MS 20470	-6	PAN	3	J89, J90, J91
21	2024	0.032	MS 20470	-4	PAN	3	J92, J93, J94
30	2024	0.063	MS 20470	-5	PAN	3	J95, J96, J97
26	2024	0.100	MS 20470	-6	PAN	3	J98, J99, J100
PLANNING SUMMARY							
13	7075	0.025				3	
32	7075	0.032				9	
12	7075	0.040				3	
10	7075	0.050				8	
33	7075	0.063				6	
11	7075	0.071				6	
15	7075	0.080				6	
7	7075	0.100				9	
22	2024	0.025				3	
21	2024	0.032				9	
19	2024	0.040				3	
20	2024	0.050				8	
30	2024	0.063				6	
24	2024	0.071				6	
23	2024	0.080				6	
26	2024	0.100				9	

TABLE 5. 5/32 DIAMETER RIVET SPECIMENS

SHEET NO.	SHEET MATERIAL	SHEET THICK (t) (IN.)	RIVET STYLE	RIVET DASH NO. (1/16")	TYPE RIVET HEAD	NO. OF SPEC. REQ'D.	ASSIGNED SPECIMEN NUMBER
32	7075	0.032	NAS 1097	-5	FLUSH	3	J101, J102, J103
12	7075	0.040	NAS 1097	-5	FLUSH	3	J104, J105, J106
11	7075	0.071	NAS 1097	-6	FLUSH	3	J107, J108, J109
15	7075	0.080	NAS 1097	-6.5	FLUSH	3	J110, J111, J112
14	7075	0.125	NAS 1097	-7.5	FLUSH	3	J113, J114, J115
21	2024	0.032	NAS 1097	-5	FLUSH	3	J116, J117, J118
19	2024	0.040	NAS 1097	-5	FLUSH	3	J119, J120, J121
24	2024	0.071	NAS 1097	-6	FLUSH	3	J122, J123, J124
23	2024	0.080	NAS 1097	-6.5	FLUSH	3	J125, J126, J127
27	2024	0.125	NAS 1097	-7.5	FLUSH	3	J128, J129, J130
12	7075	0.040	MS 20426	-5	FLUSH	3	J131, J132, J133
10	7075	0.050	MS 20426	-5.5	FLUSH	3	J134, J135, J136
11	7075	0.071	MS 20426	-6	FLUSH	3	J137, J138, J139
15	7075	0.080	MS 20426	-6.5	FLUSH	3	J140, J141, J142
14	7075	0.125	MS 20426	-7.5	FLUSH	3	J143, J144, J145
19	2024	0.040	MS 20426	-5	FLUSH	3	J146, J147, J148
20	2024	0.050	MS 20426	-5.5	FLUSH	3	J149, J150, J151
24	2024	0.071	MS 20426	-6	FLUSH	3	J152, J153, J154
23	2024	0.080	MS 20426	-6.5	FLUSH	3	J155, J156, J157
27	2024	0.125	MS 20426	-7.5	FLUSH	3	J158, J159, J160
PLANNING SUMMARY							
32	7075	0.032				3	
12	7075	0.040				6	
10	7075	0.050				3	
11	7075	0.071				6	
15	7075	0.080				6	
14	7075	0.125				6	
21	2024	0.032				3	
19	2024	0.040				6	
20	2024	0.050				3	
24	2024	0.071				6	
23	2024	0.080				6	
27	2024	0.125				6	

TABLE 6. 3/16 DIAMETER RIVET SPECIMENS

SHEET NO.	SHEET MATERIAL	SHEET THICK (t) (IN.)	RIVET STYLE	RIVET DASH NO. (1/16")	TYPE RIVET HEAD	NO. OF SPEC. REQ'D.	ASSIGNED SPECIMEN NUMBER
12	7075	0.040	NAS 1097	-6	FLUSH	3	J161, J162, J163
33	7075	0.063	NAS 1097	-6.5	FLUSH	3	J164, J165, J166
15	7075	0.080	NAS 1097	-7	FLUSH	3	J167, J168, J169
14	7075	0.125	NAS 1097	-8.5	FLUSH	3	J170, J171, J172
8	7075	0.160	NAS 1097	-9.5	FLUSH	3	J173, J174, J175
19	2024	0.040	NAS 1097	-6	FLUSH	3	J176, J177, J178
30	2024	0.063	NAS 1097	-6.5	FLUSH	3	J179, J180, J181
23	2024	0.080	NAS 1097	-7	FLUSH	3	J182, J183, J184
27	2024	0.125	NAS 1097	-8.5	FLUSH	3	J185, J186, J187
2	2024	0.160	NAS 1097	-9.5	FLUSH	3	J188, J189, J190
33	7075	0.063	MS 20426	-6.5	FLUSH	3	J191, J192, J193
11	7075	0.071	MS 20426	-7	FLUSH	3	J194, J195, J196
7	7075	0.100	MS 20426	-7.5	FLUSH	3	J197, J198, J199
14	7075	0.125	MS 20426	-8.5	FLUSH	3	J200, J201, J202
8	7075	0.160	MS 20426	-9.5	FLUSH	3	J203, J204, J205
30	2024	0.063	MS 20426	-6.5	FLUSH	3	J206, J207, J208
24	2024	0.071	MS 20426	-7	FLUSH	3	J209, J210, J211
26	2024	0.100	MS 20426	-7.5	FLUSH	3	J212, J213, J214
27	2024	0.125	MS 20426	-8.5	FLUSH	3	J215, J216, J217
2	2024	0.160	MS 20426	-9.5	FLUSH	3	J218, J219, J220
				PLANNING SUMMARY			
12	7075	0.040				3	
33	7075	0.063				6	
11	7075	0.071				3	
15	7075	0.080				3	
7	7075	0.100				3	
14	7075	0.125				6	
8	7075	0.160				6	
19	2024	0.040				3	
30	2024	0.063				6	
24	2024	0.071				3	
23	2024	0.080				3	
26	2024	0.100				3	
27	2024	0.125				6	
2	2024	0.160				6	

TABLE 7. 1/4 DIAMETER RIVET SPECIMENS

SHEET NO.	SHEET MATERIAL	SHEET THICK (t) (IN.)	RIVET STYLE	RIVET DASH NO. (1/16")	TYPE RIVET HEAD	NO. OF SPEC. REQ'D.	ASSIGNED SPECIMEN NUMBER
10	7075	0.050	NAS 1097	-7.5	FLUSH	3	J221, J222, J223
33	7075	0.063	NAS 1097	-8	FLUSH	5	J224, J225, J226, J227, J228
15	7075	0.080	NAS 1097	-8.5	FLUSH	3	J229, J230, J231
7	7075	0.100	NAS 1097	-9	FLUSH	3	J232, J233, J234
14	7075	0.125	NAS 1097	-10	FLUSH	3	J235, J236, J237
8	7075	0.160	NAS 1097	-11	FLUSH	3	J238, J239, J240
31	7075	0.190	NAS 1097	-12	FLUSH	3	J241, J242, J243
20	2024	0.050	NAS 1097	-7.5	FLUSH	3	J244, J245, J246
30	2024	0.063	NAS 1097	-8	FLUSH	5	J247, J248, J249, J250, J251
23	2024	0.080	NAS 1097	-8.5	FLUSH	3	J252, J253, J254
26	2024	0.100	NAS 1097	-9	FLUSH	3	J255, J256, J257
27	2024	0.125	NAS 1097	-10	FLUSH	3	J258, J259, J260
2	2024	0.160	NAS 1097	-11	FLUSH	3	J261, J262, J263
16	2024	0.190	NAS 1097	-12	FLUSH	3	J264, J265, J266
11	7075	0.071	MS 20426	-8.5	FLUSH	3	J267, J268, J269
15	7075	0.080	MS 20426	-8.5	FLUSH	5	J270, J271, J272, J273, J274
7	7075	0.100	MS 20426	-9	FLUSH	3	J275, J276, J277
14	7075	0.125	MS 20426	-10	FLUSH	5	J278, J279, J280, J281, J282
8	7075	0.160	MS 20426	-11	FLUSH	3	J283, J284, J285
31	7075	0.190	MS 20426	-12	FLUSH	3	J286, J287, J288
24	2024	0.071	MS 20426	-8.5	FLUSH	3	J289, J290, J291
23	2024	0.080	MS 20426	-8.5	FLUSH	5	J292, J293, J294, J295, J296
26	2024	0.100	MS 20426	-9	FLUSH	3	J297, J298, J299
27	2024	0.125	MS 20426	-10	FLUSH	5	J300, J301, J302, J303, J304
2	2024	0.160	MS 20426	-11	FLUSH	3	J305, J306, J307
16	2024	0.190	MS 20426	-12	FLUSH	3	J308, J309, J310
15	7075	0.080	MS 20470	-8.5	PAN	3	J311, J312, J313
7	7075	0.100	MS 20470	-9	PAN	3	J314, J315, J316
8	7075	0.160	MS 20470	-11	PAN	3	J317, J318, J319
23	2024	0.080	MS 20470	-8.5	PAN	3	J320, J321, J322
26	2024	0.100	MS 20470	-9	PAN	3	J323, J324, J325
2	2024	0.160	MS 20470	-11	PAN	3	J326, J327, J328
PLANNING SUMMARY							
10	7075	0.050				3	
33	7075	0.063				5	
11	7075	0.071				3	
15	7075	0.080				11	
7	7075	0.100				9	
14	7075	0.125				8	
8	7075	0.160				9	
31	7075	0.190				6	
20	2024	0.050				3	
30	2024	0.063				5	
24	2024	0.071				3	
23	2024	0.080				11	
26	2024	0.100				9	
27	2024	0.125				8	
2	2024	0.160				9	
16	2024	0.190				6	

3.5 ELEVATED TEMPERATURE TESTS

The elevated-temperature specimens were the single-shear driven rivets per MIL-STD-1312 Test 20, which has been discussed in the preceeding sections. Two types of rivets were used: 2219 heat-treated to T81 temper, and 7050-heat-treated to the T73 temper. The rivet configuration was the NAS1097, in the 3/16- and 1/4-inch diameters.

Seventy-two single shear driven specimen were fabricated for each diameter and rivet material giving a total of 288 specimens. Thirty more specimens were later added for 1/4-inch, 7050-T73 rivets. The single shear specimens were installed equally by handbucking and machine squeezing. A limited number of the specimens were also installed in minimum grip condition. The specimens for each diameter were equally divided between the two test temperatures, $250^{\circ}F$ and $350^{\circ}F$, and the three soak times 16, 96, and 288 hours.

The tests were conducted in 50K SR4-6 Universal Testing Machine using the 2500-pound range for 1/4- and 3/16-inch diameter rivets for tests at $250^{\circ}F$ and the 1000-pound range for 3/16-inch diameter rivets tests at $350^{\circ}F$. Accuracy is $\pm 0.5\%$ of load or $\pm 0.1\%$ of range, whichever is greater.

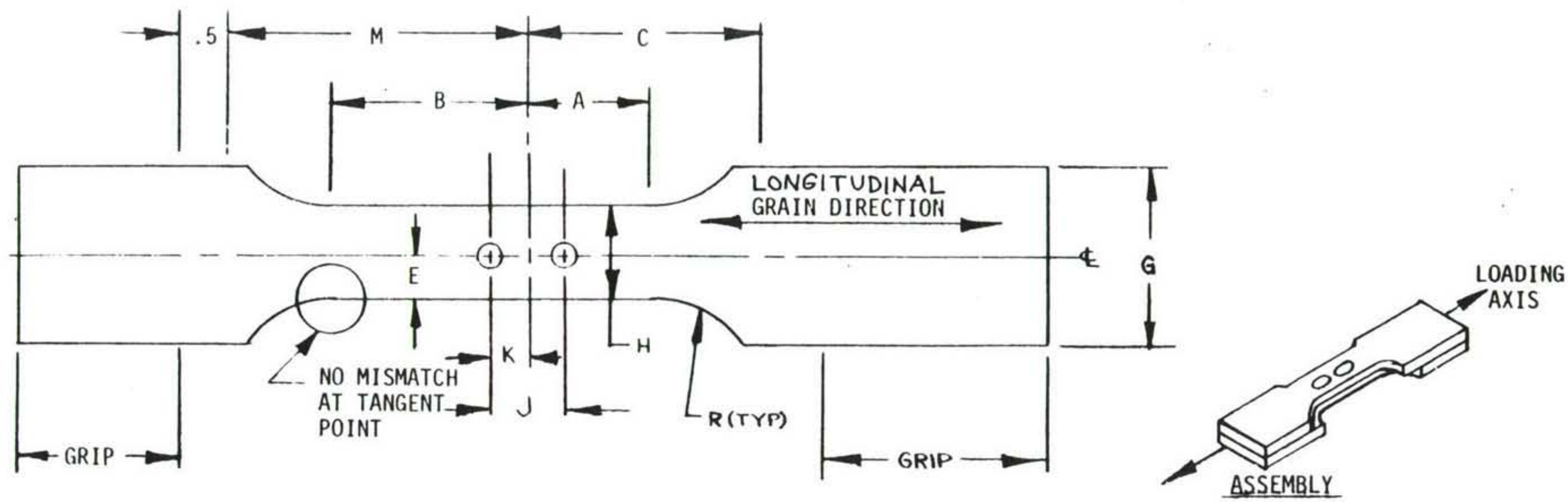
Temperature was attained using the Thermotron Chamber S/N 21-7915 and a box designed by Lockheed-Georgia Company. During soak, a Temperature Engineering Corporation oven, S/N 362868, was used for the $250^{\circ}F$ soak and a Blue M Electrical Company oven, S/N DD 120, was used for the $350^{\circ}F$ soak. Temperature during soak was accurate to less than $\pm 10^{\circ}F$. During the test, a thermocouple attached to each specimen indicated the desired temperature ($\pm 5^{\circ}F$) for 10 minutes prior to testing. Temperatures were measured on Esterline Angus Recorders. TMP185 was used for $350^{\circ}F$ test and TMP 206 was used for $250^{\circ}F$ tests. The 7050 rivets and the 2219 rivets were purchased from Blake Rivets Company. The heat-treatment was verified by the hardness tests. Additional tests were later added to verify the room-temperature strength after the soak times (16, 96, 288 hours) at $350^{\circ}F$.

3.6 JOINT FATIGUE TESTS

Comparable joint fatigue data were obtained on installed 7050-T73 rivets heat-treated to second-stage age of 355° (±5)°F, and installed 2024-T3 DD ice-box rivets obtained from the Lockheed-Georgia C-130 production line. The joint sheet material was 0.125-inch-thick 2024-T3 clad sheet obtained from existing stock. Medium-load transfer and low-load transfer type joints were used for fatigue tests. The specimen configuration are shown in Figures 7 and 8. MS20426 style rivets, 3/16-inch diameter, were used for all tests. Thirty specimens were fabricated to medium-load transfer configuration, and 42 specimens were fabricated to low-load transfer configuration. The rivets were installed in specimens by hand-bucking and machine-squeezing.

All specimen were tested in close-loop, computer-controlled testing machines (SM255 or SM258) except for specimen L27, which was tested in a manually controlled machine (SM161). All tests were conducted using a 4-inch-wide, self-aligning hydraulic grip manufactured by MTS, Inc. The tests were constant-amplitude, using a sinusoidal wave form and stress ratio R = 0.10. MIL-STD-1312 Test 21 and Lockheed-Georgia report LGER75ER0186-2 were used as guides for the testing. Calibration of the three test machine was conducted per a Lockheed procedure in accordance with MIL-C-45662A. The accuracy of these machines is ±.10% of indicted load above 10% of range. The range used was 10,000 pounds.

Stress levels for the test were selected to generate failure between 10^3 and 10^6 cycles. A few specimens were tested beyond 10^6 cycles to assist in a better definition of S/N curves.

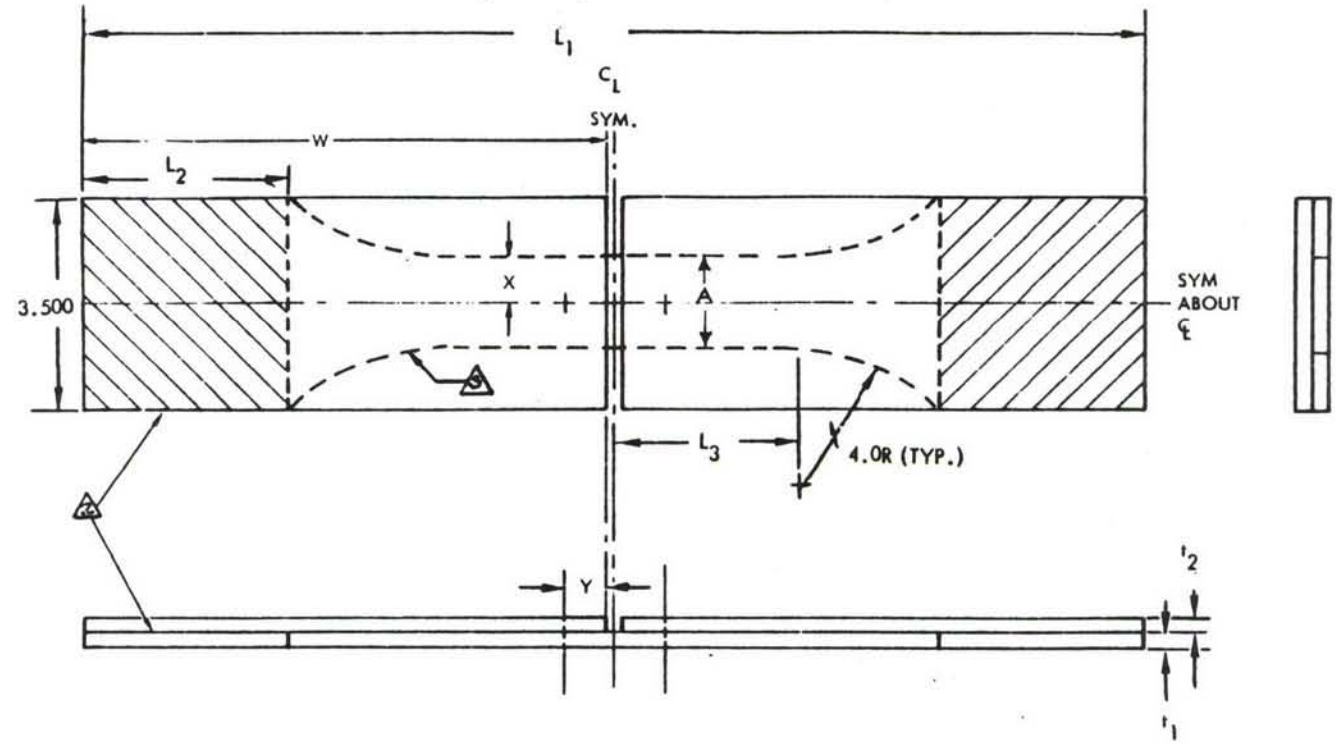


Nominal Fastener Size	Fastener Style	G	H ± .005	t	GRIP	J ± .005	K ± .005	E ± .005	A	B	M (REF)	C (REF)	R
3/16"	MS 20426	2.50"	1.126"	.125"	3.00"	.750"	.375"	.563"	1.125"	2.325'	4.23"	3.00"	3.0"

NOTES:

1. Fastener holes shall be line drilled perpendicular to sheet surface within $\frac{1}{2}^{o}$. Use drill No. 11. Ream to: Minimum -0.186; Maximum -0.196. Use integral drill for countersink using countersink tool to maintain concentricity of the countersink with the hole. The depth of countersink shall be maintained such that the installed fastener is flush within $\underline{+}$.002 - .005. Degrease before installing rivets; rivets to be installed dry. Seven specimens of each type are to be hand bucked; 8 are to be machine squeezed.
2. Apply scotchweld structural adhesive in grip area.

Figure 7. Specimen Detail, Low Load Transfer Test Specimen Joint



ASSY NO.	A, IN. ± .005	W, IN.	X, IN. ± .005	Y, IN.	t_1, IN.	t_2, IN	L_1, IN.	L_2, IN.	L_3, IN.	FAST. DIA. IN.
-1	1.123	8.900	.564	.564	.125	.125	18.00	3.50	2.850	3/16

Notes:

1. Fastener holes shall be line drilled perpendicular to sheet surface within ½°. Use drill No. 11. Ream to: Minimum — 0.186; Maximum — 0.196. Use integral drill for countersink with the hole. The depth of countersink shall be maintained such that the installed fastener is flush within + .002, - .005. Degrease before installing rivets; rivets to be installed dry. Seven specimens of each type are to be hand bucked; 8 are to be machine squeezed.

2. Apply Scotchweld structural adhesive in grip areas.

3. No mismatch at tangent point; edges machined 63 or better.

4. Lockheed Georgia Specimen Configuration - demonstrated minimum data scatter in extensive Lockheed tests.

Figure 8. Fatigue Specimen - Medium Load Transfer

SECTION IV. EXPERIMENTAL TEST RESULTS

The results of all tests are presented in this section. Wherever possible, data scatter of duplicate tests is shown and a comparison of the various parameters is described and discussed in detail.

4.1 RIVET WIRE MATERIAL

The rivet wire used in the fabrication of all the rivet configurations was procured to a vendor specification, which was coordinated with the aluminum producers. Federal Specification QQ-A-430 was used when applicable. The wire conformed to alloy 7050 chemistry and was in H-13 temper. The specification used throughout this program is presented in Appendix A.

4.2 HEAT-TREAT RESPONSE

During the negotiation for the procurement of the rivet wire and rivets, it was brought to light that the heat treatment established in Reference 1 and specified in the contract needed to be modified. This modification was a result of an extensive investigation by a rivet producer (Briles Rivet Company) in coordination with the Boeing Company. The segments of the heat-treatment cycle that needed to be changed were the solution temperature and time. This change, which reduced the solution temperature from $900(\pm 5)^{o}F$ to $890(\pm 10)^{o}F$ and the time from 15 ($\pm$1.0) minutes to 30 ($\pm$15) minutes, was coordinated with the technical monitor and added to the contract.

To verify that the change did not adversely affect the strength and the upsetting characteristics of the rivet, a number of tests were performed in these areas. The shear strength for rivet wire for the two solution heat-treat conditions is presented in Table 8, and the tensile strength for the same conditions in the Table 9. The shear strength for driven and undriven rivet are shown in Table 10. The results indicate no adverse effect on the strength properties of rivets. This was verified statistically by performing the test of significance on the data. The "F"

TABLE 8.

7050 RIVET EVALUATION
HEAT TREAT RESPONSE
RIVET WIRE

7050 - RIVET WIRE - SHEAR STRENGTH(1)

Spec No	Dia. "D" in.	"A" Area in.^{2}	Initial Condition	Batch A Load, Lbs	Batch A Fsu, Ksi	Batch B Load, Lbs	Batch B Fsu, Ksi	Remarks
1A,B	.1834	.0264	H-13	2385	45.2	2615	49.4	
2A,B	.1834	.0264	H-13	2590	49.1	2625	49.7	
3A,B	.1833	.0264	H-13	2575	48.8	2355	44.5	
4A,B	.1834	.0264	H-13	2550	48.3	2765	52.3	
5A,B	.1833	.0264	H-13	2490	47.2	2640	49.9	
6A,B	.1834	.0264	H-13	2410	45.6	2370	44.8	
7B	.1835	.0264	H-13			2580	48.8	
AV					47.4		48.5	
1A	.1223	.0117	H-13	1100	46.6			
2A	.1223	.0117	H-13	1050	44.9			
3A	.1224	.0118	H-13	1085	46.0			
4B	.1224	.0118	H-13	AV	45.8	1085	46.4	
5B	.1223	.0117	H-13			1075	45.9	
6B	.1224	.0118	H-13			1100	46.6	
					AV		46.3	
1A	.2462	.0476	H-13	4050	42.5			
2A	.2462	.0476	H-13	4050	42.5			
3B	.2460	.0475	H-13	AV	42.5	4200	44.2	
4B	.2461	.0476	H-13			4050	42.5	
						AV	43.4	

(1) Double Shear Test per Mil-Std-1312 Test No. 13

$$Fsu = \frac{\text{Load}}{2A}$$

Batch A heat treat - 900 ± 5°F for 15 ± 1 minute preciptation hardened at 250 ± 5°F for 4 hours followed by aging at 355 ± 5°F for 8 hours minimum.

Batch B heat treat - 890 ± 10°F for 30 ± 15 minutes precipitation hardened at 250 ± 5°F for 4 hours followed by 355 ± 5°F for 10 ± 2 hours.

"A" denotes specimens from Batch A.
"B" denotes specimens from Batch B.
Specimens were divided equally between Batch A and Batch B.

TABLE 9.

7050 RIVET EVALUATION
HEAT TREAT RESPONSE
RIVET WIRE

7050 - RIVET WIRE - TENSILE STRENGTH

Spec. No	Dia. in.	Area $in.^2$	Ult Load P_{TU} Lbs	Yld Load P_{TY} Lbs	F_{TU} Ksi	F_{TY} Ksi	Failure
				BATCH "A"			
1	.1225	.0118	872	745	73.9	63.1	Test Section
2	.1225	.0118	872	715	73.9	60.8	Test Section
				BATCH "B"			
1	.1224	.0118	867	720	73.5	61.0	Test Section
2	.1224	.0118	870	725	73.7	61.4	Test Section
				BATCH "A"			
1	.2464	.0477	3290	2460	69.0	51.6	Grip
2	.2464	.0477	3280	2610	68.8	54.7	Grip
				BATCH "B"			
1	.2462	.0476	3310	2630	69.5	55.3	Grip
2	.2461	.0476	3320	2640	69.7	55.5	Grip
				BATCH "A"			
1	.3090	.07499	5290	4550	70.5	60.7	Test Section
2	.3090	.07499	5370	4650	71.6	62.0	Test Section
				BATCH "B"			
1	.3090	.07499	5570	4970	74.30	66.3	Test Section
2	.3090	.07499	5600	4940	74.7	65.9	Test Section

Heat treatment of Batch A and Batch B as defined in Table 8.

TABLE 10.

7050 RIVET EVALUATION
HEAT TREAT RESPONSE
RIVETS UNDRIVEN AND DRIVEN

7050 - RIVETS SHEAR STRENGTH

Spec No.	Dia. "D" in.	Area "A" in.^{2}	Initial Condition	Batch A Load, Lbs	Batch A Fsu, Ksi	Batch B Load, Lbs	Batch B Fsu, Ksi	Remarks
1A,B	.1871	.0275	H-13	2580	46.9 (1)	2460	44.7 (1)	
2A,B	.1871	.0275	H-13	2625	47.7			Cutter not
3A,B	.1870	.0275	H-13	2770	50.4	2615	47.5	Aligned
4A,B	.1871	.0275	H-13	2720	49.4	2490	45.3	
5A,B	.1870	.0275	H-13	2595	47.2	2560	46.5	
6A,B	.1870	.0275	H-13	2565	46.6	2615	47.5	
7A,B	.1870	.0275	H-13	2445	44.5	2420	44.0	
8A,B	.1870	.0275	H-13	2540	46.2	2510	45.6	
AV					47.4		45.9	
1A	.1253	.0123	H-13	582	47.3(2)			
2A	.1253	.0123	H-13	570	46.3			
3A	.1253	.0123	H-13	590	48.0			
4B	.1252	.0123	H-13	AV	47.2	552	44.9(2)	
5B	.1252	.0123	H-13			557	45.3	
6B	.1252	.0123	H-13			565	45.9	
						AV	45.4	
1A	.2501	.0491	H-13	4250	43.3 (1)			
2A	.2501	.0491	H-13	4200	42.8			
3A	.2500	.0491	H-13	4050	42.4			
				AV	42.4			
DRIVEN RIVETS								
1A	.2501	.0491	H-13	2130	43.4 (2)			
2A	.2500	.0491	H-13	2120	43.2			
3A	.2500	.0491	H-13	2125	43.3			
4B	.2500	.0491	H-13	AV	43.3	2210	45.0 (2)	
5B	.2500	.0491	H-13			2165	44.1	
6B	.2500	.0491	H-13			2190	44.6	
AV						AV	44.6	

(1) Double Shear Test Per Mil-Std-1312 - Test No. 13
(2) Single Shear Test per Mil-Std-1312 - Test No. 20

"A" denotes specimens from Batch A.
"B" denotes specimens from Batch B.
Heat treatment of Batch A and Batch B is defined in Table 8.

and "t" computations show no difference in variability or average strength. The rivet installation parameters were also evaluated due to the change in the solution temperature and time. The results, as presented in Tables 11 and 12, met the minimum upset dimension of 1.4d and 0.3d for the buttonhead diameter and height, respectively, and where d is the actual rivet or wire diameter.

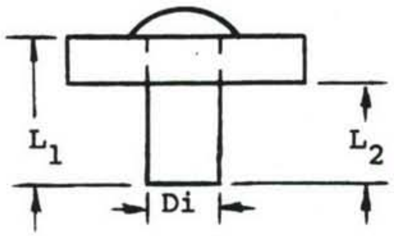
4.3 MECHANICAL PROPERTIES OF RIVET AND RIVET WIRE

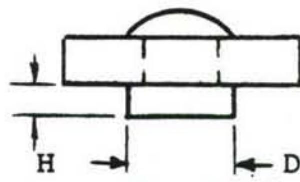
4.3.1 Rivet Wire and Rivet Shear Strength

Extensive testing was used to establish the shear strength of wire and driven and undriven rivets. Variables such as second-stage aging temperature, upper and lower temperature limits, and the method of rivet upsettability were also investigated. Tables 13 through 16 present the shear strength data for eight diameters of rivet wire ranging from 1/8-inch diameter through 3/8-inch diameter, and representing a large number of lots and aluminum alloy producers. The shear strength, double and single shear, for undriven and driven rivets are presented in Tables 17 through 29. The data are summarized in Table 30. The shear strength data for all diameters of rivet wire, all diameters of undriven rivets, and all diameters of driven rivets were collected individually and statistically analyzed to establish statistical minimum "A" and "B" values as defined by MIL-HDBK-5C. The statistical data for rivet wire, undriven rivets, and driven rivet are shown in Table 31 a and b, Table 32 a and b, and Table 33 a and b. Table 34 summarizes the entire shear strength results, which show that the wire A and B values are 40.6 and 42.7 ksi (280 and 294 MPa), the undriven rivets A and B values are 41.35 ksi and 43.77 ksi (295 and 302 MPa), and driven rivets 43.68 and 46.83 (301 and 323 MPa), and that the targets of 41 ksi for undriven rivets and 43 ksi for driven rivets were attained.

TABLE 11.

7050 RIVET EVALUATION
UPSETABILITY STUDY &
HEAT TREAT RESPONSE





Upset Diameter Measured 90° Apart. Maximum and Minimum.

Spec. No	L_1 in	L_2 in	Dia. Di in.	Dia DF1 in.	Dia DF2 in	DF AV. in	$\frac{DF}{Di}$	H in	$\frac{H}{Di}$	Upset Mode
					BATCH "A"					
1	.375	.188	.1253	.192	.193	.193	1.54	.060	0.48	Squeeze
2	.375	.188	.1253	.194	.194	.194	1.54	.070	0.56	Squeeze
3	.375	.188	.1253	.194	.190	.192	1.53	.070	0.56	Squeeze
4	.375	.188	.1253	.185	.185	.185	1.48	.070	0.56	Buck
					BATCH "B"					
1	.300	.190	.1252	.180	.182	.181	1.46	.070	0.56	Squeeze
2	.300	.190	.1252	.182	.178	.180	1.44	.070	0.56	Squeeze
3	.300	.190	.1252	.182	.178	.180	1.44	.070	0.56	Squeeze
4	.300	.190	.1252	.210	.210	.210	1.68	.050	0.40	Buck
					BATCH "A"					
1	.820	.385	.2501	.360	.373	.366	1.46	.100	0.40	Buck
2	.820	.385	.2500	.362	.355	.359	1.46	.100	0.40	Buck
3	.820	.385	.2500	.360	.358	.359	1.46	.100	0.40	Buck
					BATCH "B"					
1	.545	.280	.2500	.345	.350	.348	1.39	.130	0.52	Buck
2	.545	.280	.2500	.350	.350	.350	1.40	.120	0.48	Buck
3	.545	.280	.2500	.368	.355	.361	1.44	.100	0.40	Buck
					BATCH "A"					
* 1	.706	.280	.187	.268	.263	.266	1.42	.121	.65	All are squeezed
2	.707		.188	.264	.265	.264	1.40	.130	.69	
3	.709		.188	.269	.264	.266	1.41	.128	.68	
4	.705		.188	.279	.281	.280	1.49	.109	.58	
5	.705		.188	.281	.281	.281	1.49	.111	.59	
6	.705		.187	.282	.281	.282	1.51	.110	.59	
7	.705		.188	.292	.291	.292	1.55	.100	.53	
* 8	.706		.188	.298	.296	.297	1.58	.090	.48	
9	.704		.188	.295	.295	.295	1.57	.091	.48	
*10	.704		.188	.295	.297	.296	1.57	.091	.48	
11	.705		.188	.296	.295	.296	1.57	.095	.51	
12	.707	.280	.187	.285	.286	.286	1.53	.105	.56	

TABLE 12.

7050 RIVET EVALUATION
UPSETABILITY STUDY &
HEAT TREAT RESPONSE

Spec. No.	L_1 in.	L_2 in.	Dia. Di in.	Dia DF1 in.	Dia DF2 in.	DF AV. in.	$\frac{DF}{Di}$	H in.	$\frac{H}{Di}$	Upset Mode
					BATCH "B"					
* 1	.705	.280	.188	.265	.264	.264	1.40	.121	.64	Squeezed
2	.705		.188	.266	.269	.268	1.43	.120	.64	Twice
* 3	.705		.188	.265	.265	.265	1.41	.125	.66	
4	.704		.188	.263	.265	.264	1.40	.125	.66	
5	.706		.188	.265	.263	.264	1.40	.123	.65	
* 6	.704		.188	.277	.276	.276	1.48	.105	.56	Squeezed
* 7	.709		.187	.282	.284	.283	1.51	.110	.59	Twice
8	.709		.188	.284	.285	.284	1.51	.108	.57	
9	.708		.188	.283	.283	.283	1.51	.107	.57	
10	.705		.187	.296	.295	.296	1.58	.095	.51	
*11	.705		.188	.296	.296	.296	1.57	.094	.50	
12	.708		.188	.295	.296	.296	1.57	.095	.51	
13	.710		.187	.260	.256	.258	1.38	.132	.71	Squeezed
14	.710	.280	.188	.260	.260	.260	1.38	.126	.67	Twice

*Small Vertical Cracks were Found on Upset Head. All are Considered Acceptable per general industry criteria.

Heat treatment of Batch A and Batch B as defined in Table 8.

TABLE 13.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 WIRE

TYPE OF TEST - DOUBLE SHEAR

Diameter = 1/8 in. Area = .01241 in.^{2} Lot No. - 259011 Source - Alcoa				Diameter = 5/32 in. Area = .01858 in.^{2} Lot No. 097011 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	1172	47.1	1625	43.7
2		1163	46.9	1675	45.1
3		1131	45.6	1695	45.6
4		1173	47.3	1624	43.7
5		1228	49.3	1650	44.4
6		1150	46.3	1683	45.2
AV		1169	47.2	1659	44.6
1	"B"	1180	47.5	1725	46.4
2		1238	49.9	1730	46.5
3		1212	48.8	1670	44.9
4		1171	47.2	1742	46.9
5		1201	48.4	1705	45.8
6		1199	48.3	1705	45.8
AV		1200	48.5	1712	46.1

Heat Treat "A" - Solution treat and age at 360 $\pm^{0}_{2}$ °F

"B" - Solution treat and age at 350 $\pm^{2}_{0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 14.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 WIRE

TYPE OF TEST - DOUBLE SHEAR

Diameter = 3/16 in. Area = .0264 in.^{2} Lot No. - 097021 Source - Alcoa				Diameter = 7/32 in. Area = .03777 Lot No. 18874 Source - Kaiser	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	2360	44.7	3430	45.3
2		2300	43.6	3460	45.8
3		2360	44.7	3500	46.3
4		2320	43.9	3480	46.0
5		2300	43.6	3530	46.8
6		2290	43.4	3490	46.2
AV		2325	43.98	3482	46.1
1	"B"	2420	45.7	3760	49.8
2		2460	46.6	3740	49.5
3		2470	46.8	3720	49.2
4		2480	47.0	3760	49.8
5		2490	47.2	3750	49.6
6		2450	46.4	3760	49.8
AV		2462	46.6	3748	49.6

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 15.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 WIRE

TYPE OF TEST - DOUBLE SHEAR

Diameter = 1/4 in. Area = .0478 $in.^2$ Lot No. - R795525 Source - Conalco				Diameter = 9/32 in. Area = .06135 $in.^2$ Lot No. 259061 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	4100	42.9	5300	43.3
2		4130	43.2	5330	43.5
3		4080	42.7	5290	43.1
4		4130	43.2	5330	43.4
5		4100	42.9	5350	43.6
6		4090	42.8	5350	43.6
AV		4105	42.9	5325	43.4
1	"B"	4300	45.0	5660	46.2
2		4370	45.7	5740	46.8
3		4340	45.4	5800	47.3
4		4370	45.7	5720	46.6
5		4380	45.9	5720	46.6
6		4400	46.1	5660	46.2
AV		4360	45.6	5717	46.6

Heat Treat "A" - Solution treat and age at 360 $\pm^{0}_{2}$ °F

"B" - Solution treat and age at 350 $\pm^{2}_{0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 16.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 WIRE

TYPE OF TEST - DOUBLE SHEAR

Diameter = 5/16 in. Area = .07502 $in.^2$ Lot No. - 259071 Source - Alcoa				Diameter = 3/8 in. Area = .1086 $in.^2$ Lot No. 097051 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	6520	43.3	9800	45.2
2		6440	42.8	9500	43.7
3		6520	43.4	9680	44.6
4		6480	43.1	9930	45.7
5		6550	43.6	9790	45.0
6		6530	43.4	9830	45.2
AV		6507	43.2	9755	44.9
1	"B"	6780	45.1	10450	48.1
2		6790	45.2	9950	45.8
3		6800	45.2	9700	44.7
4		6740	44.8	10150	46.7
5		6680	44.4	10150	46.7
6		6750	44.9	10100	46.5
AV		6757	44.9	10083	46.4

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 17.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 UNDRIVEN RIVETS (MS 20470)

TYPE OF TEST - DOUBLE SHEAR

Diameter = 1/8 in Area = .01241 in.^{2} Lot No. - 259011 Source - Alcoa				Diameter = 5/32 in Area = .01928. in.^{2} Lot No. 097011 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	1172	47.1	1732	44.9
2		1163	46.9	1750	45.3
3		1131	45.6	1738	45.1
4		1173	47.3	1705	44.3
5		1223	49.3	1747	45.3
6		1150	46.3	1718	44.5
AV		1169	47.1	1732	44.9
1	"B"	1180	47.5	1838	47.7
2		1238	49.9	1765	45.8
3		1212	48.8	1825	47.4
4		1171	47.2	1795	46.7
5		1201	48.4	1780	46.1
6		1199	48.3	1785	46.3
AV		1200	48.3	1798	46.2

Heat Treat "A" - Solution treat and age at 360 $\pm^{0}_{2}$ °F

"B" - Solution treat and age at 350 $\pm^{2}_{0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 18.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 UNDRIVEN RIVETS (MS 20470)

TYPE OF TEST - DOUBLE SHEAR

Diameter = 3/16 in. Area = .02715 $in.^2$ Lot No. - 097021 Source - Alcoa				Diameter = 7/32 in. Area = .03853 $in.^2$ Lot No. 18874 Source - Kaiser	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	2520	46.4	3580	46.5
2		2520	46.4	3620	47.0
3		2520	46.4	3630	47.1
4		2560	47.1	3670	47.6
5		2530	46.6	3620	47.0
6		2520	46.4	3630	47.1
AV		2528	46.5	3625	47.05
1	"B"	2600	47.8	3830	49.7
2		2650	48.8	3860	50.1
3		2620	48.2	3920	50.9
4		2700	49.7	3880	50.3
5		2730	50.2	3870	50.2
6		2740	50.4	3890	50.5
AV		2673	49.2	3875	50.25

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 19.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 UNDRIVEN RIVETS (MS 20470)

TYPE OF TEST - DOUBLE SHEAR

Diameter = 1/4 in. Area = .04922 $in.^2$ Lot No. - R7975525 Source - Conalco				Diameter = 9/32 in. Area = .0627 $in.^2$ Lot No. 259061 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	4430	45.0	5870	46.8
2		4360	44.5	5850	46.7
3		4350	44.2	5840	46.6
4		4340	44.1	5810	46.3
5		4360	44.3	5830	46.5
6		4460	45.3	5800	46.2
AV		4383	44.5	5833	46.5
1	"B"	4500	45.7	6350	50.6
2		4540	46.1	6230	49.6
3		4500	45.7	6330	50.5
4		4600	46.7	6230	49.6
5		4590	46.6	6300	50.2
6		4490	45.6	6190	49.3
AV		4537	46.1	6272	50.0

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 20.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 UNDRIVEN RIVETS (MS 20470)

TYPE OF TEST - DOUBLE SHEAR

Diameter = 5/16 in. Area = .0783 $in.^2$ Lot No. - 259071 Source - Alcoa				Diameter = 3/8 in. Area = .11235 $in.^2$ Lot No. 097011 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	"A"	6780	43.3	10500	46.7
2		6800	43.5	10500	46.7
3		6740	43.1	11300	50.3
4		6820	43.6	112000	49.8
5		6760	43.2	10400	46.3
6		6700	42.8	10550	47.0
AV		6767	43.2	10742	47.8
1	"B"	7000	44.8	11100	49.4
2		7230	46.2	10900	48.5
3		7030	44.9	11400	50.7
4		6990	44.7	11000	49.0
5		7000	44.8	11150	49.6
6		6980	44.6	11300	50.3
AV		6903	45.0	11142	49.6

Heat Treat "A" - Solution treat and age at 360 $\pm^{0}_{2}$ °F

"B" - Solution treat and age at 350 $\pm^{2}_{0}$ °F

Test per MIL-STD-1312 - Test No. 13

TABLE 21.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 UNDRIVEN RIVETS (BAC R15 FT5XE12.5)

TYPE OF TEST - DOUBLE SHEAR

Diameter = 5/32 in. Area = .019226 $in.^2$ Lot No. - 13428 Source - Alcoa				Diameter = 3/16 in. Area = .02715 $in.^2$ Lot No. 17841 Source - Alcoa	
Spec No.	Heat Treat	Failure Load Lbs.	FSU KSI	Failure Load Lbs.	FSU KSI
1	C(1)	1780	46.3	2375	43.4
2		1760	45.8	2375	43.4
3		1760	45.8	2400	44.2
4		1740	45.4	2440	45.0
5		1740	45.3	2420	44.5
6		1750	45.7	2410	44.4
7		1750	45.5	2400	44.0
8		1760	45.8	2420	44.6
9		1750	45.5	2420	44.7
10		1750	45.5	2400	44.1
AV		1754	45.6	2408	44.23

(1) HEAT TREATED BY BLAKE RIVET CO.

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

C - Solution treat and age at 355 ± 5 °F

Test per MIL-STD-1312 - Test No. 13

TABLE 22.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 1/8 in.
Actual .1256 in.
Lot No. - 259011
Source - Alcoa

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in.	Area in.^{2}	FSU KSI	Type of Upset
1	"A"	718	0.129	.01306	54.9	M
2		670	0.129	.01306	51.3	M
3		692	0.129	.01306	53.0	M
4		666	0.129	.01306	51.0	M
5		674	0.129	.01306	51.6	M
6		656	0.129	.01306	50.2	M
7		678	0.129	.01306	51.9	H
8		700	0.129	.01306	53.6	H
9		650	0.129	.01306	49.8	H
10		630	0.129	.01306	51.5	
AV		673	0.129	.01306	51.5	
1	"B"	690	0.129	.01306	52.8	M
2		691	0.129	.01306	52.9	M
3		766	0.129	.01306	58.6	M
4		722	0.129	.01306	55.3	M
5		736	0.129	.01306	56.3	M
6		738	0.129	.01306	56.5	M
7		729	0.129	.01306	55.8	M
8		710	0.129	.01306	54.4	M
9		758	0.129	.01306	58.0	M
10		718	0.129	.01306	55.0	M
11		697	0.129	.01306	53.1	M
12		750	0.129	.01306	57.4	H
13		711	0.129	.01306	57.4	H
14		744	0.129	.01306	57.0	H
15		748	0.129	.01306	57.0	H
AV		727	0.129	.01306	55.7	

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 23.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 5/32 in.
Actual .1587 in.
Lot No. - 097011
Source - Alcoa

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia "d" in.	Area in.^{2}	FSU KSI	Type of Upset
1	"A"	1060	.162	.02060	51.4	M
2		1050	.162	.02060	51.0	M
3		990	.162	.02060	48.1	M
4		1020	.162	.02060	49.5	M
5		1030	.162	.02060	50.0	M
6		1020	.162	.02060	49.5	M
7		995	.162	.02060	48.3	H
8		1050	.162	.02060	51.0	H
9		1010	.162	.02060	49.0	H
10		1055	.162	.02060	51.2	
AV		1028	.162	.02060	49.9	
1	"B"	1095	.162	.02060	53.2	M
2		1100	.162	.02060	53.4	M
3		1075	.162	.02060	52.2	M
4		1045	.162	.02060	50.7	M
5		1120	.162	.02060	54.4	H
6		1095	.162	.02060	53.2	H
7		1115	.162	.02060	54.1	H
8		1088	.162	.02060	52.8	
AV		1092	.162	.02060	53.0	

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 24.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 3/16 in.
Actual .1864 in.
Lot No. - 097021
Source - Alcoa

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in	Area in.^{2}	FSU KSI	Type of Upset
1	"A"	1480	.194	.02954	50.1	M
2		1485	.194	.02954	50.2	M
3		1460	.194	.02954	49.4	M
4		1465	.194	.02954	49.6	M
5		1460	.194	.02954	49.4	M
6		1450	.194	.02954	49.1	M
7		1450	.194	.02954	49.1	M
8		1445	.194	.02954	48.9	H
9		1475	.194	.02954	49.9	H
10		1495	.194	.02954	50.6	H
AV		1467	.194	.02954	49.7	
1	"B"	1565	.194	.02954	53.0	M
2		1565	.194	.02954	53.0	M
3		1545	.194	.02954	52.3	M
4		1594	.194	.02954	54.0	H
5		1575	.194	.02954	53.3	H
6		1575	.194	.02954	53.3	H
AV		1570			53.1	

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 25.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 7/32 in.
Actual .2215 in.
Lot No. - 18874
Source - Kaiser

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in.	Area $in.^2$	FSU KSI	Type of Upset
1	"A"	1960	.2240	.03939	49.8	M
2		1950	.2240	.03939	49.5	M
3		1945	.2240	.03939	49.4	M
4		1975	.2240	.03939	50.1	H
5		1940	.2240	.03939	49.2	H
6		1970	.2240	.03939	50.0	H
AV		1957	.2240	.03939	49.6	
1	"B"	2045	.2240	.03939	51.9	M
2		2080	.2240	.03939	52.8	M
3		2045	.2240	.03939	51.9	M
4		2020	.2240	.03939	51.3	H
5		2115	.2240	.03939	53.7	H
6		2153	.2240	.03939	54.6	H
7		2025	.2240	.03939	52.0	H
8		2135	.2240	.03939	54.2	H
AV		2077	.2240	.03939	52.8	

Heat Treat "A" - Solution treat and age at 360 $\pm^{0}_{2}$ °F

"B" - Solution treat and age at 350 $\pm^{2}_{0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 26.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 1/4 in.
Actual .2505 in.
Lot No. - R7975525
Source - Conalco

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in.	Area in.^{2}	FSU KSI	Type of Upset
1	"A"	2330	.254	.05064	46.0	M
2		2340	.254	.05064	46.2	M
3		2410	.254	.05064	47.6	M
4		2335	.254	.05064	46.1	M
5		2415	.254	.05064	47.7	M
6		2410	.254	.05064	47.6	H
7		2345	.254	.05064	46.3	H
8		2335	.254	.05064	46.1	H
AV		2365	.254	.05064	46.7	
1	"B"	2400	.254	.05064	47.4	M
2		2405	.254	.05064	47.5	M
3		2415	.254	.05064	47.7	M
4		2550	.254	.05064	50.3	M
5		2455	.254	.05064	48.5	H
6		2505	.254	.05064	59.5	H
7		2450	.254	.05064	48.3	H
AV		2454	.254	.05064	48.4	

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 27.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 9/32 in.
Actual .2826
Lot No. - 259061
Source - Alcoa

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in.	Area $in.^2$	FSU KSI	Type of Upset
1	"A"	3120	.286	.0642	48.6	M
2		3170	.286	.0642	49.4	M
3		3190	.286	.0642	49.7	M
4		3200	.286	.0642	49.8	H
5		3340	.286	.0642	50.0	H
6		3420	.286	.0642	53.3	H
7		3240	.286	.0642	50.5	H
8		3200	.286	.0642	49.8	H
AV		3235	.286	.0642	50.1	
1	"B"	3260	.286	.0642	50.8	M
2		3350	.286	.0642	52.2	M
3		3400	.286	.0642	52.9	M
4		3540	.286	.0642	55.1	H
5		3260	.286	.0642	50.8	H
6		3360	.286	.0642	52.3	H
7		3400	.286	.0642	52.9	H
8		3600	.286	.0642	56.1	H
AV		3396	.286	.0642	52.9	

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 28.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 5/16 in.
Actual .3157 in.
Lot No. - 259071
Source - Alcoa

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in.	Area in.^{2}	FSU KSI	Type of Upset
1	"A"	3700	.317	.0789	46.9	M
2		3830	.317	.0789	48.5	M
3		3660	.317	.0789	46.1	M
4		3740	.317	.0789	47.4	H
5		3840	.317	.0789	48.4	H
6		3840	.317	.0789	48.4	H
AV		3768	.317	.0789	47.7	
1	"B"	3970	.317	.0789	50.0	M
2		3760	.317	.0789	47.1	M
3		4000	.317	.0789	50.7	M
4		3840	.317	.0789	48.1	H
5		3890	.317	.0789	49.0	H
6		3860	.317	.0789	48.9	H
AV		3887			49.3	

Heat Treat "A" - Solution treat and age at 360 $\pm^{0}_{2}$ °F

"B" - Solution treat and age at 350 $\pm^{2}_{0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 29.

7050-T73 (RIVET QUALIFICATION TESTS)

MATERIAL - 7050-T73 DRIVEN RIVETS (MS 20470)

TYPE OF TEST - SINGLE SHEAR

Diameter = Nominal 3/8 in.
Actual .3785 in.
Lot No. - 097051
Source - Alcoa

Spec No.	Heat Treat	Failure Load Lbs.	Hole Dia. "d" in.	Area $in.^2$	FSU KSI	Type of Upset
1	"A"	5720	.385	0.1164	49.1	M
2		5550	.385	0.1164	47.6	M
3		5560	.385	0.1164	47.8	M
4		5720	.385	0.1164	49.1	M
5		5720	.385	0.1164	49.1	M
6		5600	.385	0.1164	48.1	M
7		5640	.385	0.1164	48.4	M
8		5800	.385	0.1164	49.6	M
9		5780	.385	0.1164	48.3	M
10		5620	.385	0.1164	48.7	M
AV		5671	.385	0.1164	48.7	
1	"B"	5650	.385	0.1164	48.5	M
2		5900	.385	0.1164	50.7	M
3		6180	.385	0.1164	53.1	M
4		6260	.385	0.1164	53.7	M
5		6140	.385	0.1164	52.2	M
6		6180	.385	0.1164	53.1	M
7		5960	.385	0.1164	51.1	M
8		6430	.385	0.1164	55.2	M
9		5860	.385	0.1164	50.3	M
10		5920	.385	0.1164	50.8	M
AV		6048	.385	0.1164	51.9	

Heat Treat "A" - Solution treat and age at 360 $^{+0}_{-2}$ °F

"B" - Solution treat and age at 350 $^{+2}_{-0}$ °F

H = Hand Bucked

M = Machine Squeezed

Test per MIL-STD-1312 - Test No. 20

TABLE 30.

7050-T73 RIVET QUALIFICATION DATA

SUMMARY - SHEAR STRENGTH FOR 7050-T73

WIRE AND RIVETS

Dia. in. (mm)	Average Shear Strength, KSI, (MPA)					
	Wire		Undriven Rivet		Driven Rivet	
	Heat Treat		Heat Treat		Heat Treat	
	A	B	A	B	A	B
1/8 (3.2)	47.2 (325)	48.5 (334)	47.1 (325)	48.3 (333)	51.5 (355)	55.7 (384)
5/32 (4.0)	44.6 (307)	46.1 (318)	44.9 (309)	46.2 (318)	49.9 (344)	53.0 (365)
3/16 (4.8)	43.9 (303)	46.6 (321)	46.5 (321)	49.2 (339)	49.7 (343)	53.1 (366)
7/32 (5.5)	46.1 (318)	49.6 (342)	47.1 (325)	50.3 (347)	49.6 (342)	52.7 (363)
1/4 (6.3)	42.9 (296	45.6 (314)	44.5 (307)	46.1 (318)	46.7 (322)	48.4 (333)
9/32 (7.1)	43.4 (299)	46.6 (321)	46.5 (321)	50.0 (345)	50.4 (347)	52.9 (365)
5/16 (7.9)	43.3 (298)	44.9 (308)	43.2 (298)	45.0 (310)	47.7 (329)	48.9 (337)
3/8 (9.5)	44.9 (314)	46.4 (320)	47.8 (330)	49.6 (342)	48.7 (336)	50.9 (351)

Heat Treat:

A = Second Stage Age at 360^{+0}_{-2} °F

B = Second Stage Age at 350^{+2}_{-0} °F

TABLE 31 (a). STATISTICAL EVALUATION OF WIRE SHEAR STRENGTH

NUMBER OF DATA IS 96.

FOR THIS AMOUNT OF DATA, THE ONE-SIDED TOLERANCE LIMIT FACTORS FOR THE NORMAL DISTRIBUTION ARE 2.692 FOR A ALLOWABLES AND 1.532 FOR B ALLOWABLES.

ORDERED DATA

42.70	42.80	42.80	42.90	42.90	43.10	43.10	43.20	43.20	43.30
43.30	43.40	43.40	43.40	43.40	43.50	43.60	43.60	43.60	43.60
43.60	43.70	43.70	43.70	43.90	44.40	44.40	44.60	44.70	44.70
44.70	44.80	44.90	44.90	45.00	45.00	45.10	45.10	45.10	45.20
45.20	45.20	45.20	45.30	45.40	45.60	45.70	45.70	45.70	45.70
45.80	45.80	45.90	45.90	45.90	45.90	46.00	46.10	46.20	46.20
46.20	46.30	46.40	46.40	46.50	46.50	46.60	46.60	46.60	46.70
46.70	46.80	46.80	46.80	46.80	46.80	46.90	47.00	47.00	47.20
47.30	47.50	47.60	47.70	47.90	48.10	48.10	48.20	48.50	49.20
49.50	49.60	49.70	49.80	49.80	50.40				

TEST VALUES

AVERAGE VALUE	MAXIMUM VALUE	MINIMUM VALUE	STANDARD DEVIATION
45.66	50.40	42.70	1.87

1 (ONE) VALUE IS OUT OF 2.5 SIGMA RANGE

TABLE 31 (b)

CHI-SQUARE CHECK FOR NORMAL DISTRIBUTION

MINIMUM VALUE IN INTERVAL	NUMBER OF DATA IN INTERVAL
40.97	0.
41.91	3.
42.84	21.
43.78	7.
44.72	15.
45.66	20.
46.59	16.
47.53	6.
48.47	2.
49.41	5.
50.34	
TOTAL	95.

CHI-SQUARE IS 33.21 GREATER THAN 16.92,SO DATA IS NOT NORMALLY DISTRIBUTED.

A1 ,FROM ONE-SIDED TOLERANCE LIMITS,IS 40.61 Estimated A value

100.0 PERCENT OF THE DATA FALLS ABOVE THE COMPUTED A ALLOWABLE OF 40.61

B2 IS 42.72

99.0PERCENT OF THE DATA FALLS ABOVE THE COMPUTED B ALLOWABLE OF 42.72

TABLE 32 (a) STATISTICAL EVALUATION OF UNDRIVEN RIVET SHEAR STRENGTH

RIVETS

NUMBER OF DATA IS 95.

FOR THIS AMOUNT OF DATA, THE ONE-SIDED TOLERANCE LIMIT FACTORS FOR THE NORMAL

DISTRIBUTION ARE 2.695 FOR A ALLOWABLES AND 1.534 FOR B ALLOWABLES.

ORDERED DATA

42.80	43.10	43.20	43.30	43.50	43.60	44.10	44.20	44.30	44.30
44.30	44.50	44.60	44.70	44.80	44.80	44.90	44.90	45.00	45.10
45.30	45.30	45.30	45.60	45.60	45.70	45.70	45.80	46.10	46.10
46.20	46.20	46.30	46.30	46.30	46.30	46.40	46.40	46.40	46.40
46.50	46.50	46.60	46.60	46.60	46.60	46.70	46.70	46.70	46.70
46.80	46.90	47.00	47.00	47.00	47.10	47.10	47.10	47.10	47.20
47.30	47.40	47.50	47.60	47.70	47.70	47.80	48.20	48.30	48.40
48.50	48.80	48.80	49.00	49.30	49.30	49.40	49.60	49.60	49.70
49.70	49.80	49.90	50.10	50.20	50.20	50.20	50.30	50.30	50.40
50.50	50.50	50.60	50.70	50.90					

TEST VALUES

AVERAGE VALUE	MAXIMUM VALUE	MINIMUM VALUE	STANDARD DEVIATION
46.99	50.90	42.80	2.10

0 (ZERO) VALUES ARE OUT OF 2.5 SIGMA RANGE

TABLE 32 (b)

CHI-SQUARE CHECK FOR NORMAL DISTRIBUTION

MINIMUM VALUE IN INTERVAL	NUMBER OF DATA IN INTERVAL
41.76	1.
42.80	5.
43.85	10.
44.90	12.
45.95	24.
46.99	15.
48.04	7.
49.09	10.
50.14	11.
51.18	0.
52.23	
TOTAL	95.

CHI-SQUARE IS 19.88 GREATER THAN 16.92,SO DATA IS NOT NORMALLY DISTRIBUTED.

A1 ,FROM ONE-SIDED TOLERANCE LIMITS,IS 41.35 Estimated A value

100.0 PERCENT OF THE DATA FALLS ABOVE THE COMPUTED A ALLOWABLE OF 41.35

B2 IS 43.77

93.7PERCENT OF THE DATA FALLS ABOVE THE COMPUTED B ALLOWABLE OF 43.77

TABLE 33 (a) STATISTICAL EVALUATION OF DRIVER RIVETS SHEAR STRENGTH

HAND AND MACHINED

NUMBER OF DATA IS 136.

FOR THIS AMOUNT OF DATA, THE ONE-SIDED TOLERANCE LIMIT FACTORS FOR THE NORMAL DISTRIBUTION ARE 2.627 FOR A ALLOWABLES AND 1.489 FOR B ALLOWABLES.

ORDERED DATA

46.00	46.10	46.10	46.20	46.30	46.40	46.90	47.40	47.40	47.50
47.60	47.60	47.60	47.70	47.70	47.70	47.80	48.00	48.10	48.20
48.30	48.30	48.40	48.40	48.50	48.50	48.50	48.50	48.60	48.70
48.70	48.70	48.90	48.90	49.00	49.10	49.10	49.10	49.10	49.10
49.20	49.30	49.30	49.40	49.40	49.40	49.40	49.50	49.50	49.50
49.60	49.60	49.70	49.70	49.70	49.80	49.80	49.80	49.90	50.00
50.10	50.10	50.20	50.20	50.30	50.30	50.30	50.40	50.60	50.70
50.70	50.70	50.70	50.70	50.90	50.90	50.90	51.00	51.20	51.20
51.30	51.30	51.40	51.40	51.60	51.90	51.90	51.90	52.00	52.10
52.20	52.20	52.30	52.30	52.70	52.80	52.80	52.80	52.90	52.90
52.90	52.90	52.90	52.90	53.10	53.10	53.10	53.10	53.10	53.10
53.30	53.30	53.40	53.60	53.80	54.00	54.10	54.20	54.30	54.30
54.40	54.60	54.90	54.90	55.10	55.20	55.20	55.80	56.00	56.30
56.50	56.90	57.20	57.40	58.00	58.60				

TEST VALUES

AVERAGE VALUE	MAXIMUM VALUE	MINIMUM VALUE	STANDARD DEVIATION
50.96	58.60	46.00	2.77

2 (TWO) VALUES ARE OUT OF 2.5 SIGMA RANGE

TABLE 33 (b)

CHI-SQUARE CHECK FOR NORMAL DISTRIBUTION

MINIMUM VALUE IN INTERVAL	NUMBER OF DATA IN INTERVAL
44.03	0.
45.41	6.
46.80	13.
48.19	31.
49.57	27.
50.96	17.
52.35	20.
53.73	11.
55.12	6.
56.51	3.
57.89	
TOTAL	134.

CHI-SQUARE IS 11.62 LESS THAN 16.92,SO DATA IS NORMALLY DISTRIBUTED.

A1 ,FROM ONE-SIDED TOLERANCE LIMITS,IS 43.68

100.0 PERCENT OF THE DATA FALLS ABOVE THE COMPUTED A ALLOWABLE OF 43.68

B1,FROM ONE-SIDED TOLERANCE LIMITS,IS 46.83

95.6PERCENT OF THE DATA FALLS ABOVE THE COMPUTED B ALLOWABLE OF 46.83

TABLE 34.

SUMMARY OF SHEAR STRENGTH DATA
USING ALL DIAMETER HEAT TREAT(1)
AND INSTALLATION METHODS.

Material Designation	No. of Spec.	Shear Strength, Lbs. (MPA) Average	Minimum	Statistical - Min.[3] "A" Value	"B" Value
Wire	96	45.7 (315)	42.7 (294)	40.6 (280)	42.7 (294)
Rivet (Undriven)	95	47.0 (320)	42.8 (295)	41.35 (285)	43.77 (302)
Rivet[2] (Driven)	136	51.0 (352)	46.0 (317)	43.68 (301)	46.83 (323)

(1) The heat treatment was evenly divided as to second stage aging - one half of specimens were aged at 350^{+2}_{-0}F and the other half aged at 360^{+2}_{-0}F.

(2) 52 specimens were hand bucked and 84 specimens were machine squeezed.

(3) The statistical values "A" & "B" are as defined in MIL-HDBK-5, "Military Standardization Handbook Metallic Materials and Elements for Aerospace Vehicle Structure".

4.3.2 Corrosion Tests

The corrosion investigation included both the corrosion compatibility of the 7050-T73 rivet compared with that of 2024-T31 ice-box DD rivet, and the stress corrosion susceptibility of the 7050-T73 wire. The results of each of these corrosion conditions are discussed below.

4.3.2.1 Corrosion Compatability

The six corrosion panels, which consisted of two materials (2024-T3 and 7075-T73) and three finishes (as-received, sulfuric-acid anodize and alodine), were exposed to 5% salt solution. Each panel had a total of 36 rivets divided in three segments: dry installation, corrosion-inhibited sealant installation, and wet with zinc chromate installation. The rivets were 8 rivets/segment 7050-T73, 3/16-inch and 3/8-inch diameters and four 3/16-inch diameter 2024-T31-DD rivets.

After the exposure, the panels were photographed, as shown in Figure 9, for comparison. All rivets were then removed and the holes and rivets visually inspected for evidence of corrosion. The photograph in Figure 10 is a view of one panel at a higher magnification, which shows the typical rivet pattern. Two of the 7050 rivets in the bare 2024-T3 had lost a significant portion of the head. In general the corrosion of the 7050-T73 rivets was more extensive in the bare panels than was that of the 2024-T31 rivets. The alodine 2024 panel exhibited the next most severe corrosion, with both rivets affected to the same degree. The other panels exhibited only superficial corrosion with 2024 rivets, slightly less than the 7050 rivets. No effect of sealant or type of upsetting could be detected. All panels were inclined 5 to 10 degrees in the corrosion chamber with the rivet heads up.

No evidence of any stress corrosion failure of the rivet wire, loaded at 75% of yield, was encountered after the 30 days in the salt solution.

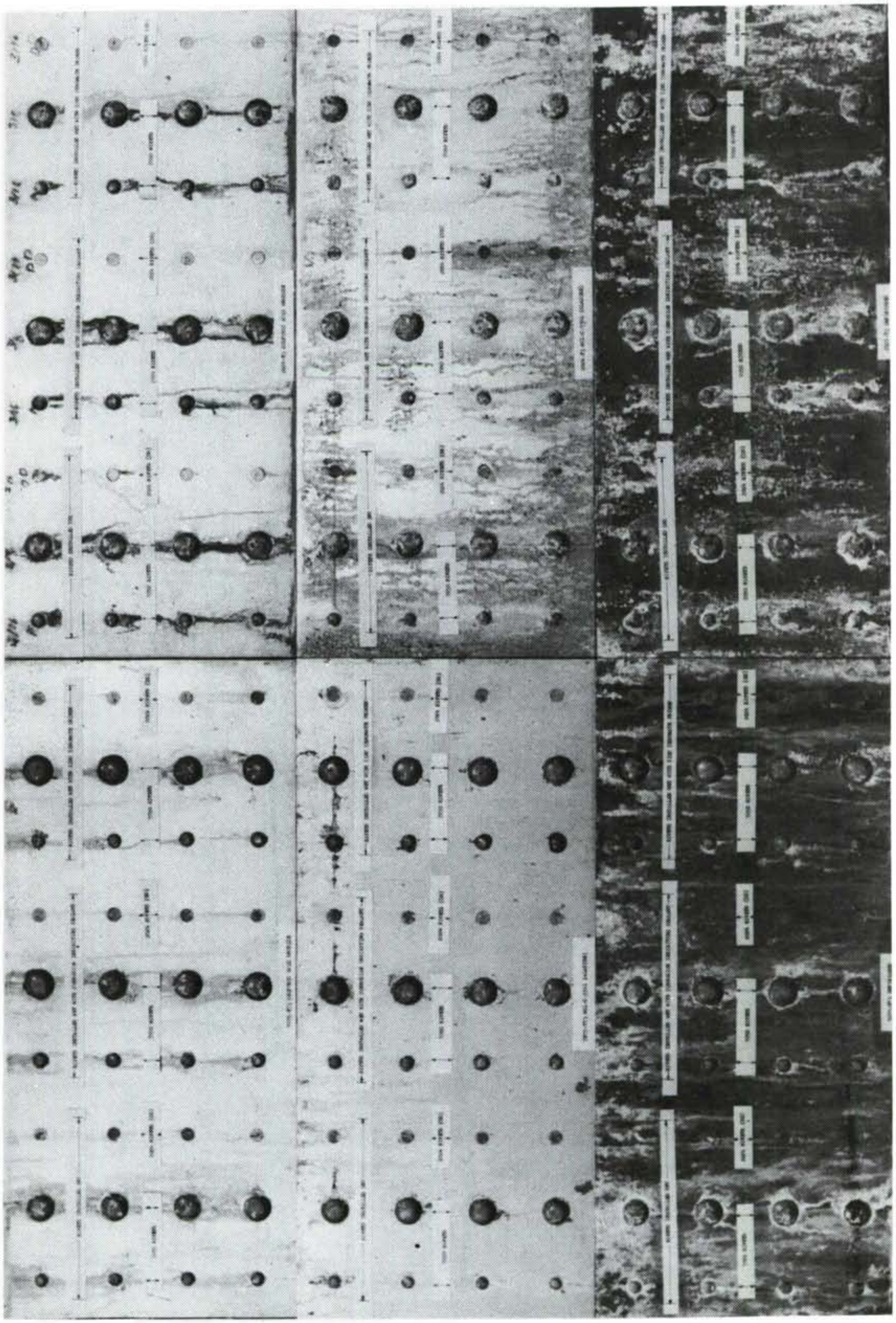


Figure 9. Corrosion Panels

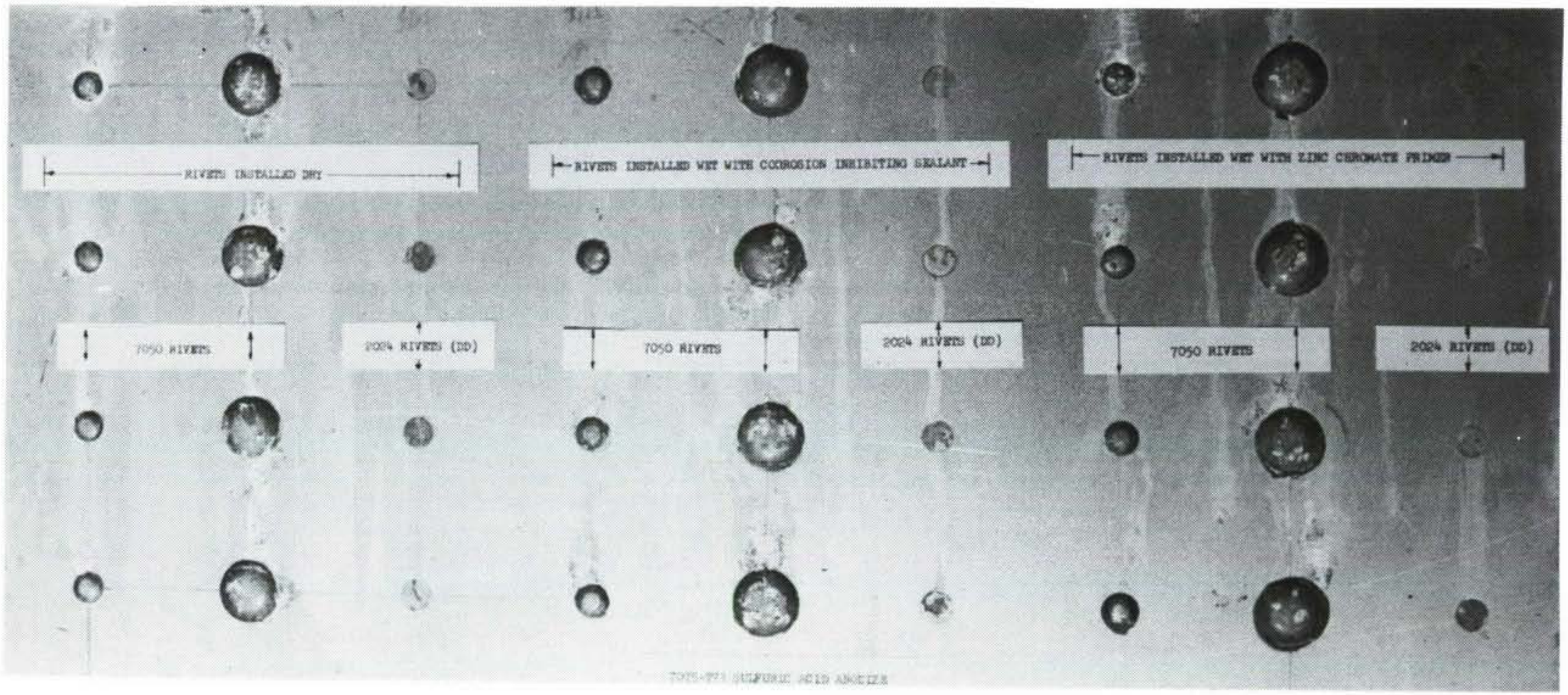


Figure 10. A Typical Corrosion Panel

4.4 JOINT DESIGN ALLOWABLES

The joint design allowables tests consisted of the static joint allowables and the rivet shear strength.

4.4.1 Static Joint Allowable

The static joint allowables for the 7050-T73 rivets were performed on two rivet configurations: NAS 1097 and MS 20426, and two aluminum alloy sheet materials: 7075-T6 and 2024-T3. Limited tests were run on the Universal head rivet, MS 20470. The test parameters and the analysis of the data were in accordance with the accepted Guidelines of the MIL-HDBK-5C. A proposal for each rivet and joint sheet material was prepared by the author and submitted to MIL-HDBK-5 Fastener Task Group (FTG) for their review, comments, and final recommendation.

The allowables derived from this program, after the approval of the FTG, will be added to chapter 8 of MIL-HDBK-5 for industry use. The approved MIL-HDBK proposals will be incorporated as Volume II subsequent to final approval. Briefly, the data in the proposal consist of graphic presentations of yield and ultimate joint loads in a non-dimensional format, and the tabulated joint allowables.

4.4.2 Rivet Shear Strength

The shear strengths of the driven rivets were established by single shear tests. The minimum allowable shear strength or shear cutoff strength was computed using the statistical approach of paragraph 9.4.1.5 of the Guidelines of MIL-HDBK-5. The data and the computation of final allowable shear strength are also a part of the proposal to FTG and Volume II as discussed above.

4.5 ELEVATED TEMPERATURE OF ALUMINUM RIVETS

Elevated-temperature tests were performed to make a comparison of the elevated-temperature properties of 7050-T73 aluminum rivet and 2219-T81

aluminum rivet. Alloy 2219 is assumed to be a high temperature aluminum alloy that retains appreciable strength at temperature.

Two temperatures, 250° and $350^{\circ}F$, and three soak times for each temperature, 16, 96, and 288 hours were used. Two rivet diameters were also selected. The test was a single-shear driven test. The test results for the above parameters are shown in Tables 35 through 38, and plotted in Figures 11 and 12. The data indicate that there is an initial drop of 15% below room temperature when the 7050-T73 is tested at $250^{\circ}F$. A soak time after 16 hours does not seem to have any further effect. Some degradation and soak time effect applies to the 2219-T81 rivet. In testing at $350^{\circ}F$, there is a greater reduction of room temperature properties of 7050-T73(42%) compared with 2219-T81 (34%). The soak time increase does contribute to further degradation of properties at $350^{\circ}F$.

The shear strength of 1/4-inch diamter 7050-T73 rivet soaked at $350^{\circ}F$ for 16, 96, and 288 hours and tested at room temperature show a reduction of strength of 9% at 16 hours of soak, 22% at 96 hours, and 26% at 288 hours. The soak time appears more significant when the tests were performed at room temperature. It is evident from the data that 7050-T73 can have the same strength as the 2219-T81 at the two temperatures and soaks, except the 288-hours soak, where 2219-T81 is 10% higher than 7050-T73 in shear strength.

4.6 FATIGUE STRENGTH OF RIVETED JOINTS

The fatigue life of riveted joints containing bucked and squeezed 7050-T73 and 2024-T31 aluminum rivets installed in 2024T3 clad aluminum sheet was evaluated. Thirty joint fatigue specimens, each of low-load and medium-load transfers were fabricated, with half of the specimens containing each rivet system and tested under constant-amplitude fatigue and stress ratio, R = 0.10. Approximately the same stress levels were used for each, and sufficient numbers of stress levels were selected to give a well-defined S/N curve between 10^{4} and 10^{7} cycles.

The fatigue test results for both rivet systems and load transfer (joint geometries) are presented in Tables 39 and 40. Figures 13 and 14 present S/N curve for 7050-73 riveted low and medium load transfer joints,

while Figures 15 and 16 present similar data for 2024-T31 riveted joints. To obtain a direct comparison of the two rivet systems, all low-load transfer joint data are plotted in Figure 17, and all medium load transfer joint data are shown in Figure 18.

A study of the comparative fatigue data of the 7050-T73 and 2024-T31 riveted joints does not indicate any difference in fatigue life behavior between the two systems, implying that they could be used interchangeably where the fatigue life of the joint is under consideration.

TABLE 35.

ALUMINUM ALLOY RIVETS TEMPERATURE EVALUATION

SINGLE SHEAR DRIVEN TEST DATA

Rivet Dia. Nom. in.	Rivet Dia. Act in.	Hole Dia. Act in.	7050-T73 Rivet Failure Load Lbs. Machine Squeeze Min Grip	7050-T73 Rivet Failure Load Lbs. Machine Squeeze Max Grip	7050-T73 Rivet Failure Load Lbs. Hand Buck Min Grip	7050-T73 Rivet Failure Load Lbs. Hand Buck Max Grip	2219-T81 Rivet Failure Load Lbs. Machine Squeeze Min Grip	2219-T81 Rivet Failure Load Lbs. Machine Squeeze Max Grip	2219-T81 Rivet Failure Load Lbs. Hand Buck Min Grip	2219-T81 Rivet Failure Load Lbs. Hand Buck Max Grip	Dia Act in.
16 Hours soak and test at 250°F											
3/16	.1860	0.194	1257	1236	1346	1403	1035	1020	1109	1133	.1867
				1235	1273	1249		1038		1110	
				1250		1260		1030		1075	
				1199		1230		1026		1075	
				1195				1016		1091	
96 Hours Soak and test at 250°F											
	.1860		1216	1162	1250	1200	1025	1027	1015	1020	
3/16		0.194		1325	1190	1175		1046		1000	.1867
				1265		1182		1142		1052	
				1216		1267		1195		1066	
				1220				1078		1010	
288 Hours Soak and test at 250°F											
			1215	1226	1218	1190	1065	1001	1000	985	
				1220	1246	1217		1133		1077	
3/16	.1860	0.194		1195		1222		1050		1000	.1867
				1242		1217		1078		1055	
				1199				1089		1042	
16 Hours Soak and test at 350°F											
			838	841	919	888	854	822	924	914	
				872		846		847	842	852	
3/16	.1860	0.194		856		879		796		872	.1687
				829		924		829		833	
				812		880		850			
96 Hours Soak and test at 350°F											
			859	768	740	802	919	850	797	872	
		0.194		766		794		845	822	822	.1867
3/16	.1860			785		728		820		802	
				774		760		835		817	
				777		820		844			

TABLE 36.

ALUMINUM ALLOY RIVETS TEMPERATURE EVALUATION

SINGLE SHEAR DRIVEN TEST DATA

Rivet Dia.			7050-T73 Rivet Failure Load Lbs.				2219-T81 Rivet Failure Load Lbs.				Dia
		Hole Dia.	Machine Squeeze		Hand Buck		Machine Squeeze		Hand Buck		Act in.
Nom. in.	Act in.	Act in.	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	
288 Hours soak and test at 350°F											
3/16	.1860	0.194	912	688	739	754	897	856	826	943	.1867
				720	773	842		884		892	
				800		810		936		848	
				742		763		856		870	
				748				804		918	
16 Hours Soak and test at 250°F											
1/4	.2500	0.256	1943	1980	1988	1980	1880	1984	1915	1860	
				2004	1975	1990	1894	1987	1970	1875	
				1980		2033		1915	1915	1863	.2514
				1940		2002		1910			
				2005							
96 Hours Soak and test at 250°F											
				1988	1920	1968	1980	1860	1888	1868	1900
1/4	.2500	.256		1895		1870		1882	1826	1900	
				1990		1980		1915		1886	.2574
				1955		1978		1887		1908	
				1945		2050		1884			
288 Hours Soak and test at 250°F											
			1930	1872	1898	1940	1850	1835	1802	1810	
1/4	.2500	.256		1990	1945	1877		1768		1809	.2514
				1962		1968		1887		1817	
				2000		1920		1861		1837	
				1986				1828		1853	

TABLE 37.

ALUMINUM ALLOY RIVETS TEMPERATURE EVALUATION

SINGLE SHEAR DRIVEN TEST DATA

Rivet Dia.			7050-T73 Rivet	Failure Load Lbs.			2219-T81 Rivet		Failure Load Lbs.		Dia
		Hole Dia.	Machine Squeeze		Hand Buck		Machine Squeeze		Hand Buck		Act in.
Nom. in.	Act in.	Act in.	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	
16 Hours Soak and test at 350°F											
			1432	1355	1345	1375	1507	1490	1643	1485	
1/4	.2500	.256		1408		1418		1445		1522	.2514
				1398		1363		1470		1482	
				1331		1425		1498		1465	
				1355		1365		1452		1483	
96 Hours Soad and test at 350°F											
			1258	1323	1238	1240	1496	1407	1488	1550	
1/4	.2500	.256		1278		1255		1485		1520	
				1260		1269		1490		1440	
				1262		1293		1455		1466	
				1285		1280		1391		1405	
288 Hours Soak and test at 350 °F											
			1304	1223	1173	1213	1420	1436	1504	1537	
				1201	1212	1225		1511		1410	
1/4	.2500	.256		1151		1218		1455		1394	
				1250		1222		1355		1423	
				1270				1365		1433	
16 Hours Soak at 350°F and test at Room Temperature											
				2115		2080					
1/4	.2500	.256		2170		2005					
				2170		2020					
				2150		2045					
				2150		2050					

TABLE 38.

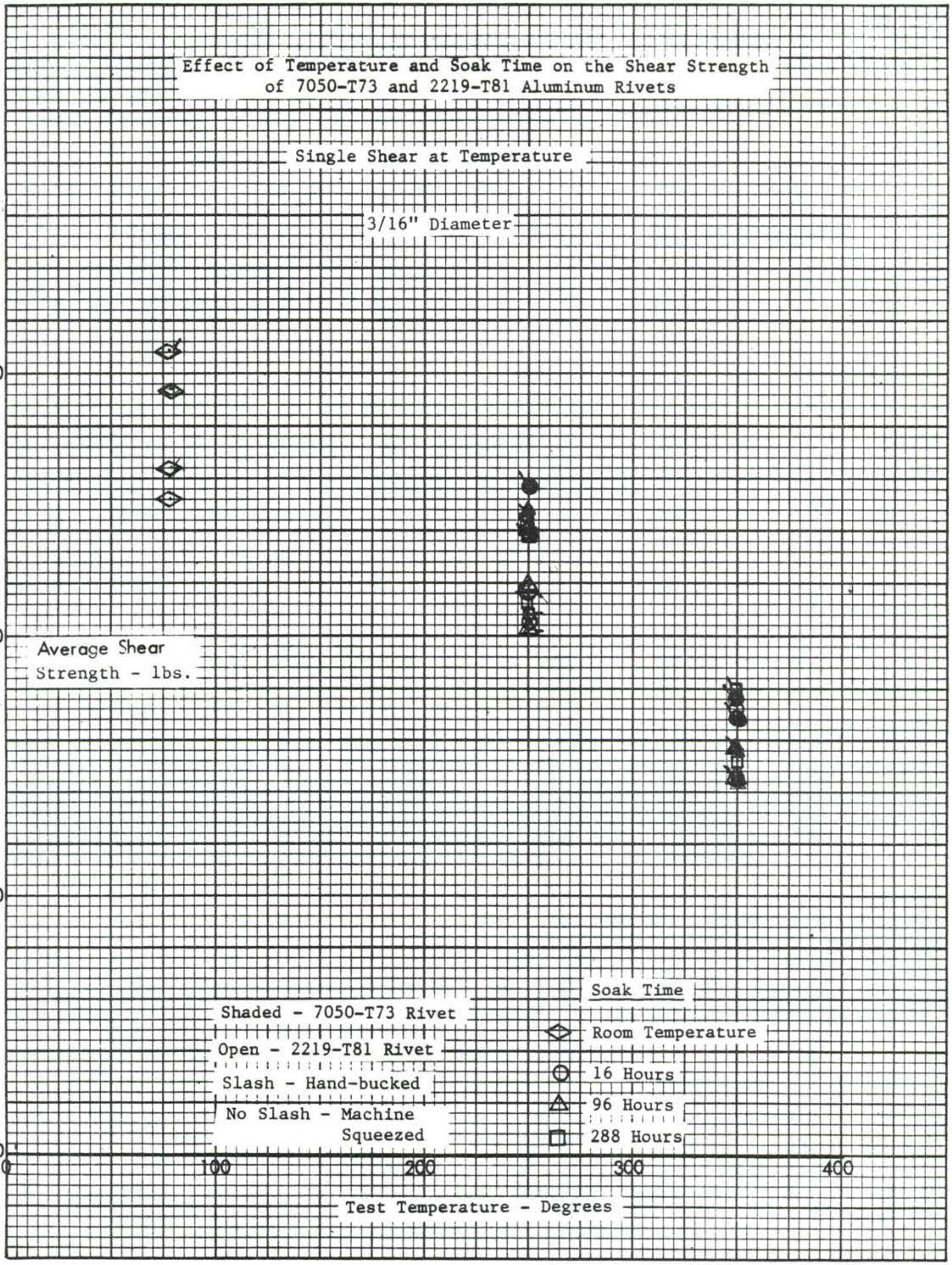
ALUMINUM ALLOY RIVETS TEMPERATURE EVALUATION

SINGLE SHEAR DRIVEN TEST DATA

Rivet Dia.		Hole Dia.	7050-T73 Rivet Failure Load Lbs. Machine Squeeze		Hand Buck		2219-T81 Rivet Failure Load Lbs. Machine Squeeze		Hand Buck		Dia Act in.
Nom. in.	Act in.	Act in.	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	
96 Hours Soak at 350°F and test at Room Temperature											
				1875		1825					
		.256		1830		1775					
	.2500			1840		1855					
1/4				1870		1830					
				1830		1810					
288 Hours Soak at 350°F and test at Room Temperature											
				1725		1730					
1/4	.2500	.256		1735		1725					
				1730		1705*					
				1720		1735					
				1735		1735					

*Bad test - Gap in test specimen.

Rivet Dia.		Hole Dia.	7050-T73 Rivet Failure Load Lbs. Machine Squeeze		Hand Buck		2219-T81 Rivet Failure Load Lbs. Machine Squeeze		Hand Buck		Dia Act in.
Nom. in.	Act in.	Act in.	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	Min Grip	Max Grip	
Room Temperature - No Soak											
				1480		1595		1256		1327	.1867
3/16	.1864	.194		1485		1575		1235		1335	
				1460		1575		1238		1243	
				1465		1495		1267		1250	
				1460		1475		1310		1310	
Room Temperature - No Soak											
				2330		2455		2245		2230	.2514
1/4		.256		2340		2505		2240		2195	
				2410		2450		2227		2250	
				2335		2410		2244		2185	
				2415		2345		2239		2255	
										2235	



Effect of Temperature and Soak Time on the Shear Strength of 7050-T73 and 2219-T81 Aluminum Rivets
Single Shear at Temperature
3/16" Diameter
1500
1000
500
0
Average Shear Strength - lbs.
Shaded - 7050-T73 Rivet
Open - 2219-T81 Rivet
Slash - Hand-bucked
No Slash - Machine Squeezed
Soak Time
Room Temperature
16 Hours
96 Hours
288 Hours
0
100
200
300
400
Test Temperature - Degrees
K+E 10 X 10 TO ½ INCH 46 1022
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

Figure 11.

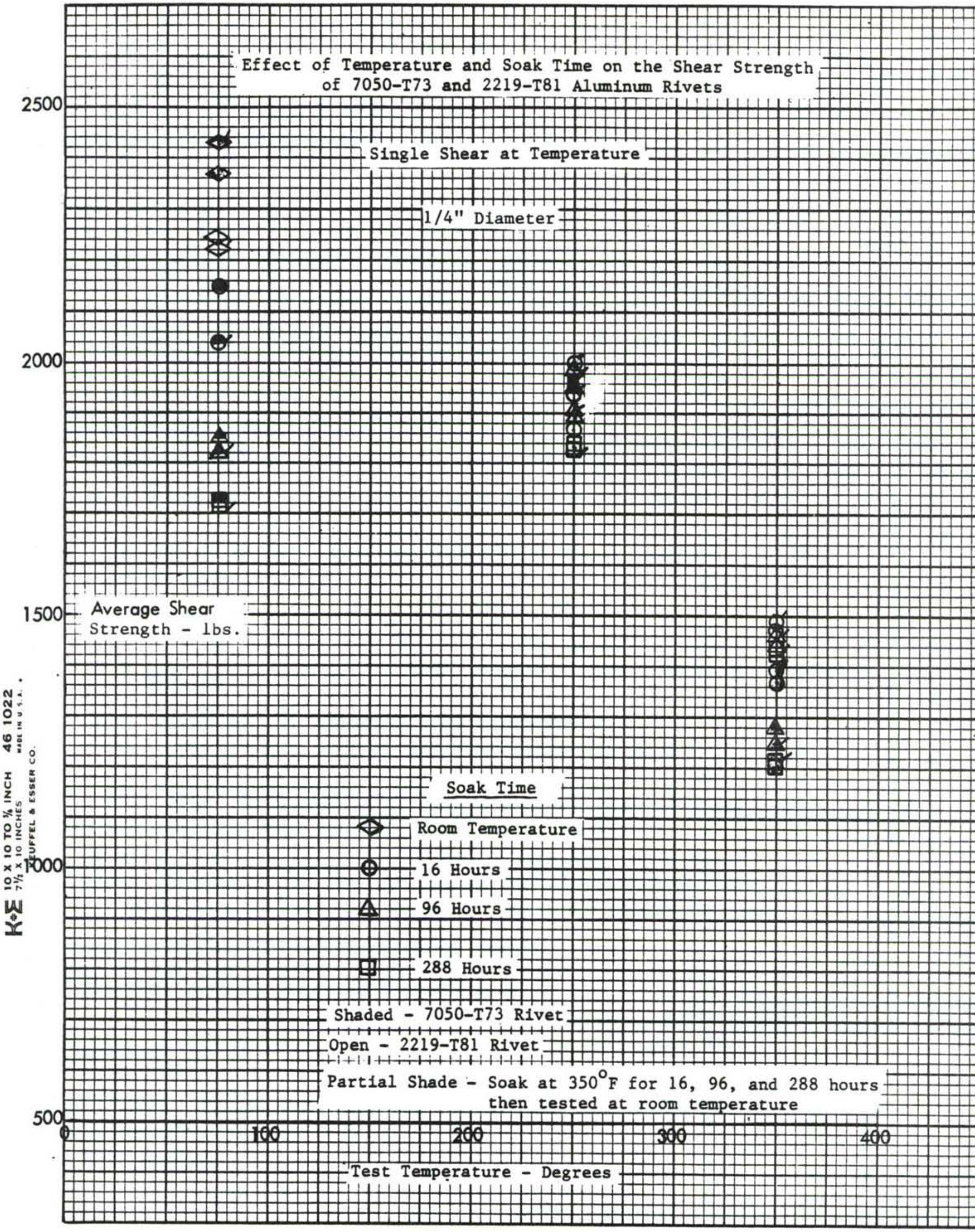

Effect of Temperature and Soak Time on the Shear Strength of 7050-T73 and 2219-T81 Aluminum Rivets
Single Shear at Temperature
1/4" Diameter
Average Shear Strength - lbs.
2500
2000
1500
1000
500
Soak Time
Room Temperature
16 Hours
96 Hours
288 Hours
Shaded - 7050-T73 Rivet
Open - 2219-T81 Rivet
Partial Shade - Soak at 350°F for 16, 96, and 288 hours then tested at room temperature
0
100
200
300
400
Test Temperature - Degrees
K+E 10 X 10 TO ½ INCH 46 1022
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

Figure 12.

TABLE 39.

7050 RIVET EVALUATION

FATIGUE TESTS - LOW LOAD TRANSFER

Spec No.	Rivet Type	Upset Method	Width	Thickness CS in.	Thickness BS in.	Area in^2	Max Stress KSI	Min Load lbs	Max Load lbs	Cycles to Failure	Failure Mode
L1	7050	HB	1.130	.1210	.1224	.2750	25.0	687.5	6875	46,520	F
L2	Rivet	HB	1.130	.1212	.1213	.2741	30.0	822.3	8223	43,000	F
L3		HB	1.125	.1213	.1212	.2728	20.0	545.6	5456	160,718	F
L4		HB	1.130	.1210	.1210	.2738	17.8	486.8	4868	140,310	F
L5		HB	1.130	.1207	.1204	.2724	11.0	490.4	4904	1,666,764	F
L6		HB	1.130	.1215	.1217	.2748	35.0	961.8	9618	10,900	F
L7		HB	1.129	.1212	.1215	.2740	16.0	438.4	4384	131,414	F
L8		MS	1.128	.1230	.1230	.2460	20.0	492.0	4920	78000	F
L9	7050	MS	1.122	.1216	.1210	.2722	25.0	680.5	6805	36000	F
L10	Rivet	MS	1.131	.1234	.1232	.2789	30.0	836.7	8367	13207	F
L11		MS	1.130	.1231	.1232	.2783	10.0	278.3	2783	5,800,000	R_1
L12		MS	1.126	.1233	.1233	.2777	13.0	361.0	3610	265,355	F
L13		MS	1.126	.1214	.1210	.2729	11.0	300.2	3002	467,509	F
L14		MS	1.126	.1235	.1233	.2779	16.0	444.6	4446	149,338	F
L15		MS	1.126	.1235	.1234	.2780	11.0	305.8	3058	4,162,000	R_2
L16		HB	1.130	.1203	.1204	.2712	20.0	542.4	5424	60,456	F
L17	2024	HB	1.120	.1215	.1213	.2719	25.0	679.8	6798	29,454	F
L18	Rivet	HB	1.126	.1230	.1229	.2769	16.0	443.0	4430	196,048	F
L19		HB	1.126	.1206	.1208	.2718	30.0	815.4	8154	11,652	F
L20		HB	1.126	.1210	.1214	.2729	13.0	354.8	3548	337,450	F
L21		HB	1.128	.1208	.1210	.2728	11.0	300.1	3001	487,012	F
L22		HB	1.128	.1212	.1212	.2734	9.0	246.1	2461	2,000,000	R_3
L23		MS	1.126	.1212	.1213	.2731	30.0	819.3	8193	19,706	F
L24		MS	1.127	.1217	.1214	.2740	25.0	685.0	6850	38,096	F
L25	2024	MS	1.128	.1219	.1218	.2749	20.0	549.8	5498	79,000	F
L26	Rivet	MS	1.126	.1217	.1218	.2742	10.0	274.3	2743	1,602,432	F
L27		MS	1.124	.1218	.1219	.2739	11.0	301.3	3013	540,000	F
L28		MS	1.125	.1217	.1218	.2739	13.0	356.1	3561	201,372	F
L29		MS	1.126	.1214	.1213	.2733	16.0	437.3	4373	244,126	F
L30		MS	1.124	.1219	.1214	.2735	11.0	300.8	3008	8,000,000	R_4

HB = Hand Buck, MS = Machine Squeeze

F = Material Failure, R = Rivet Failure, all specimens continued to failure

R_1 = 7,332,667, R_2 = 6,882,000, R_3 = 10,630,000, R_4 = 8,620,000

CS = Countersunk Side, BS = Bucked Side

TABLE 40.

7050 RIVET EVALUATION

FATIGUE TESTS - MEDIUM LOAD TRANSFER

Spec No.	Rivet Type	Deform Method(1)	Width Inch	Thickness, Inch Solid Piece	Split Piece	Nominal Max Stress KSI(3)	(2) Load, lbs	Frequency HZ	Cycles to Failure (F) (4) or Runout (R)	
M1	7050	HB	1.124	0.121	0.120	25.0	3400	10	22,632	F
M2	7050	HB	1.124	0.121	0.122	20.0	2720	10	52,864	F
H3	7050	HB	1.126	0.124	0.123	15.0	2094	10	138,108	F
M4	7050	HB	1.126	0.124	0.122	30.0	4188	10	12,891	F
M5	7050	HB	1.127	0.124	0.122	9.5	1327	10	1,590,000	F of Rivet
M6	7050	HB	1.126	0.120	0.122	12.0	1621	10	205,079	F
M7	7050	HB	1.127	0.124	0.122	10.0	1397	10	Malfunction at 210,000	
M8	7050	MS	1.125	0.121	0.123	30.0	4083	10	16,887	F
M9	7050	MS	1.125	0.124	0.122	25.0	3488	10	27,777	F
M10	7050	MS	1.124	0.120	0.121	20.0	2698	10	35,288	F
M11	7050	MS	1.126	0.124	0.121	15.0	2094	10	134,439	F
M12	7050	MS	1.126	0.124	0.121	12.0	1675	10	169,852	F
M13	7050	MS	1.125	0.120	0.122	10.0	1350	10	393,841	F
M14	7050	MS	1.125	0.124	0.121	12.0	1674	10	480,947	F
M15	7050	MS	1.125	0.124	0.121	10.0	1395	10	5,200,000	R
M16	2024	HB	1.126	0.124	0.121	30.0	4188	10	18,330	F
M17	2024	HB	1.128	0.124	0.121	25.0	3498	10	17,405	F
M18	2024	HB	1.126	0.124	0.121	20.0	2792	10	41,679	F
M19	2024	HB	1.126	0.121	0.123	15.0	2043	10	153,306	F
M20	2024	HB	1.126	0.124	0.122	12.0	1675	10	296,231	F
M21	2024	HB	1,125	0.121	0.122	10.0	1361	10	534,399	F
M22	2024	HB	1.126	0.121	0.113	9.5	1294	10	269,397	F
M23	2024	MS	1.126	0.124	0.123	15.0	2094	10	149,435	F
M24	2024	MS	1.125	0.124	0.120	30.0	4185	10	14,189	F
M25	2024	MS	1.125	0.124	0.122	25.0	3488	10	38,342	F
M26	2024	MS	1.126	0.124	0.122	20.0	2792	10	79,372	F
M27	2024	MS	1.126	0.124	0.123	9.5	1326	10	1,276,749	F
M28	2024	MS	1.126	0.124	0.123	12.0	1675	10	539,959	F
M29	2024	MS	1.124	0.124	0.122	10.0	1394	10	831,419	F
M30	2024	MS	1.126	0.124	0.122	12.0	1675	10	269292	F

(1) HB designates hand bucked; MS designates machine squeezed
(2) All Loading was constant amplitude, R = 0.10
(3) All Stress reported are gross area stress
(4) "FH" indicates failure of sheet material at countersink
"F of Rivet" indicates failure of Rivet

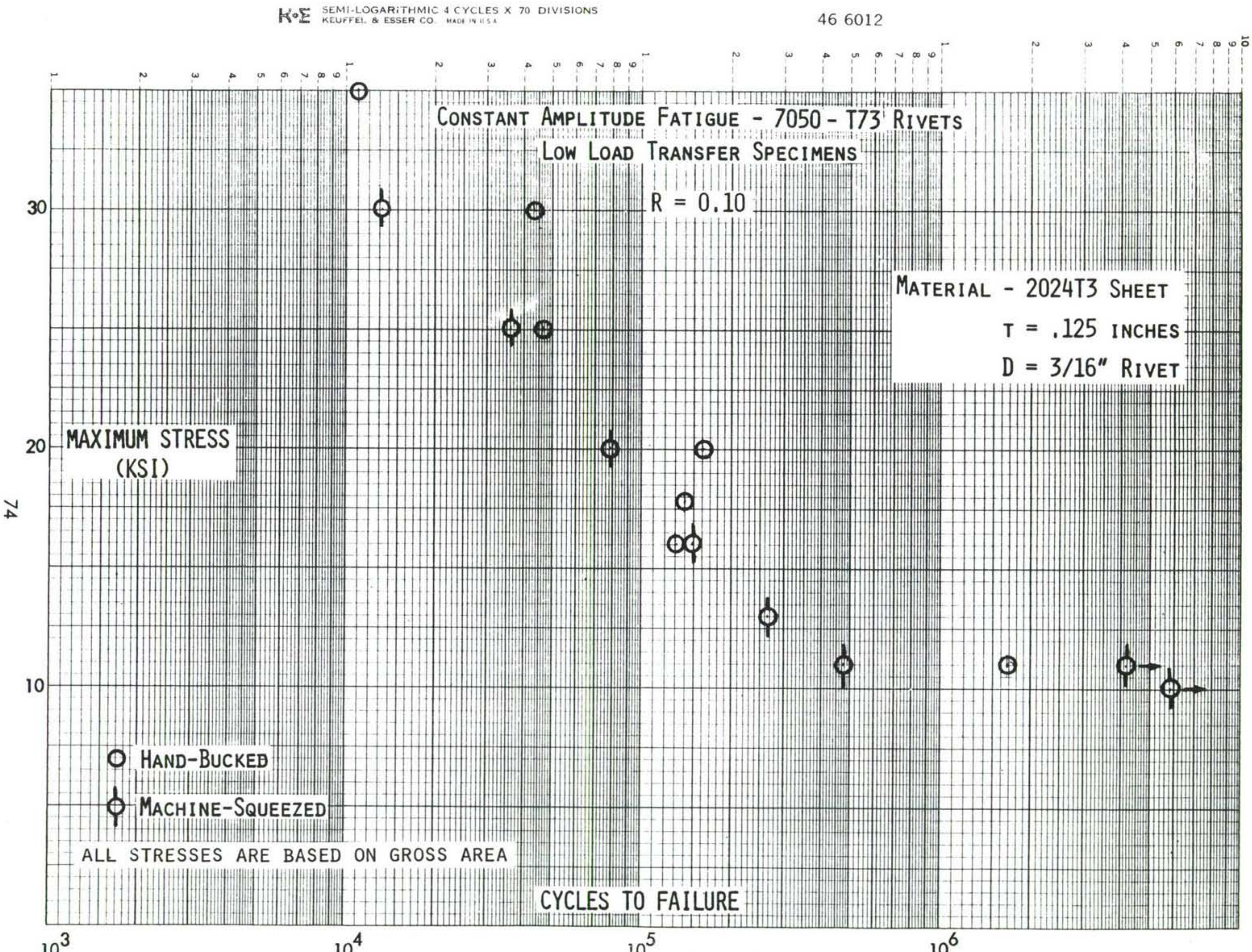

K·E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6012
CONSTANT AMPLITUDE FATIGUE - 7050 - T73 RIVETS
LOW LOAD TRANSFER SPECIMENS
R = 0.10
MATERIAL - 2024T3 SHEET
T = .125 INCHES
D = 3/16" RIVET
MAXIMUM STRESS
(KSI)
30
20
10
HAND-BUCKED
MACHINE-SQUEEZED
ALL STRESSES ARE BASED ON GROSS AREA
CYCLES TO FAILURE
10^3
10^4
10^5
10^6

Figure 13.

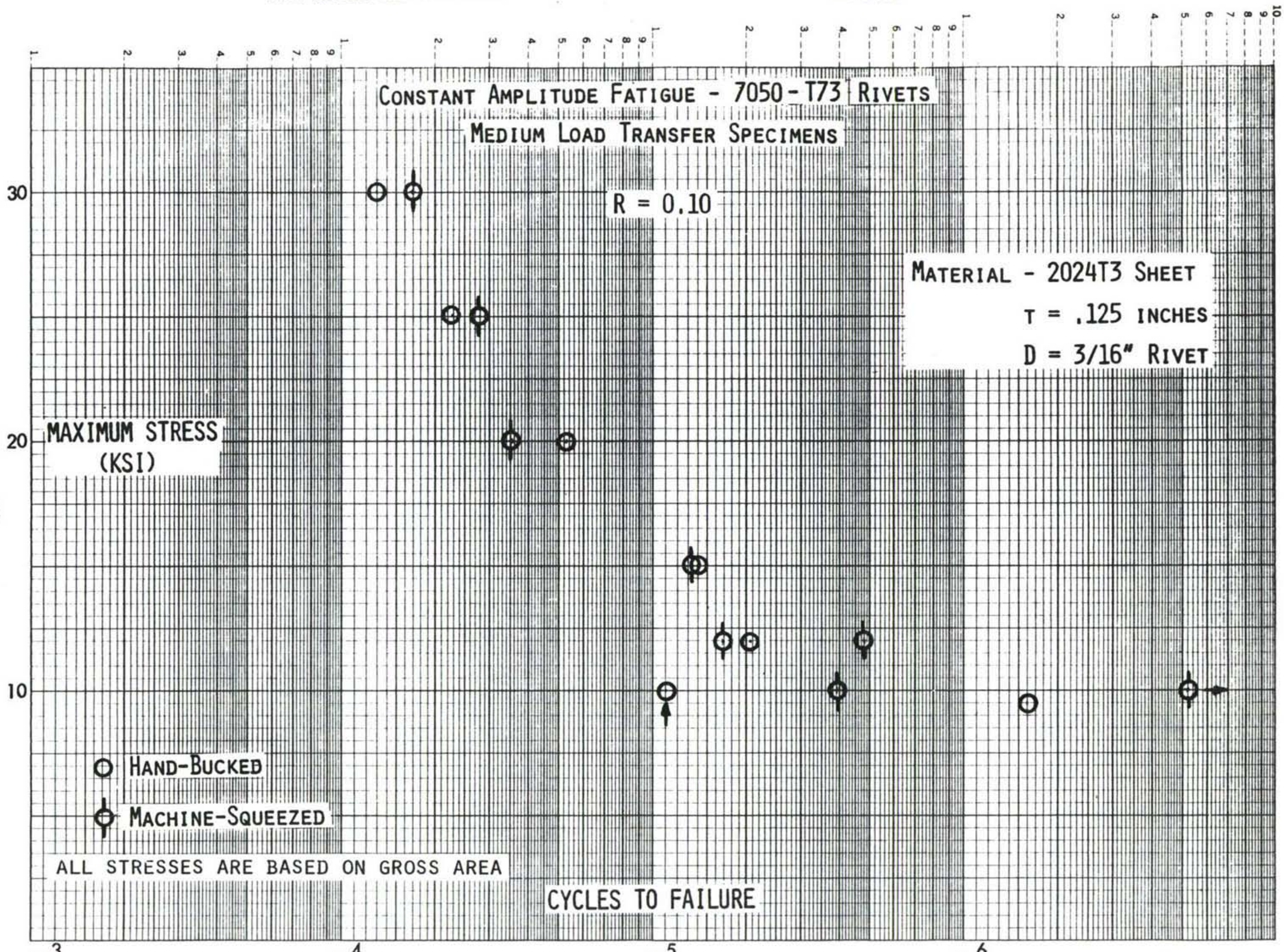
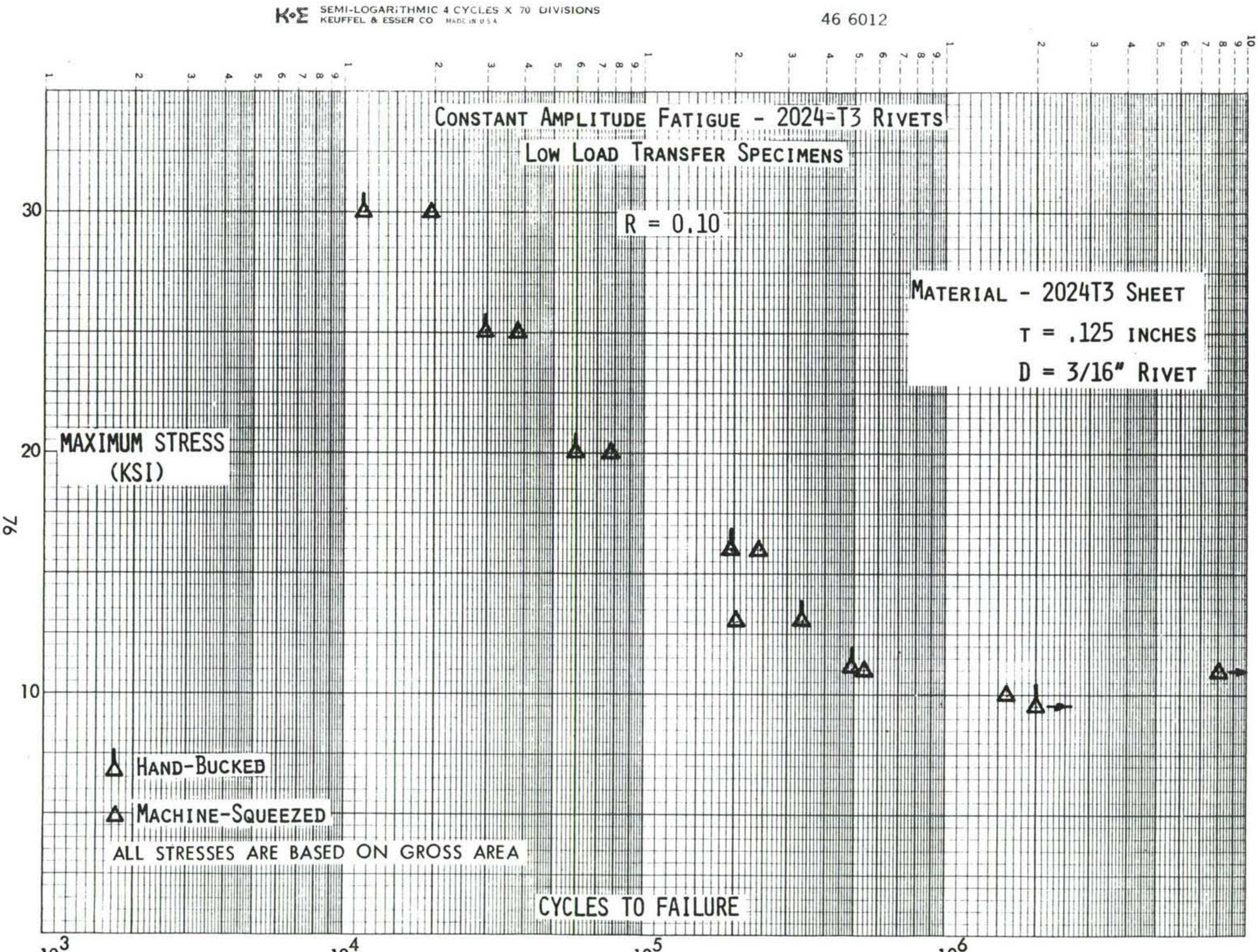

CONSTANT AMPLITUDE FATIGUE - 7050-T73 RIVETS
MEDIUM LOAD TRANSFER SPECIMENS
R = 0.10
MATERIAL - 2024T3 SHEET
T = .125 INCHES
D = 3/16" RIVET
MAXIMUM STRESS
(KSI)
30
20
10
HAND-BUCKED
MACHINE-SQUEEZED
ALL STRESSES ARE BASED ON GROSS AREA
CYCLES TO FAILURE
10^3
10^4
10^5
10^6

Figure 14.



K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO MADE IN U.S.A.
46 6012
CONSTANT AMPLITUDE FATIGUE - 2024-T3 RIVETS
LOW LOAD TRANSFER SPECIMENS
R = 0.10
MATERIAL - 2024T3 SHEET
T = .125 INCHES
D = 3/16" RIVET
MAXIMUM STRESS
(KSI)
30
20
10
HAND-BUCKED
MACHINE-SQUEEZED
ALL STRESSES ARE BASED ON GROSS AREA
CYCLES TO FAILURE
10^3
10^4
10^5
10^6

Figure 15.

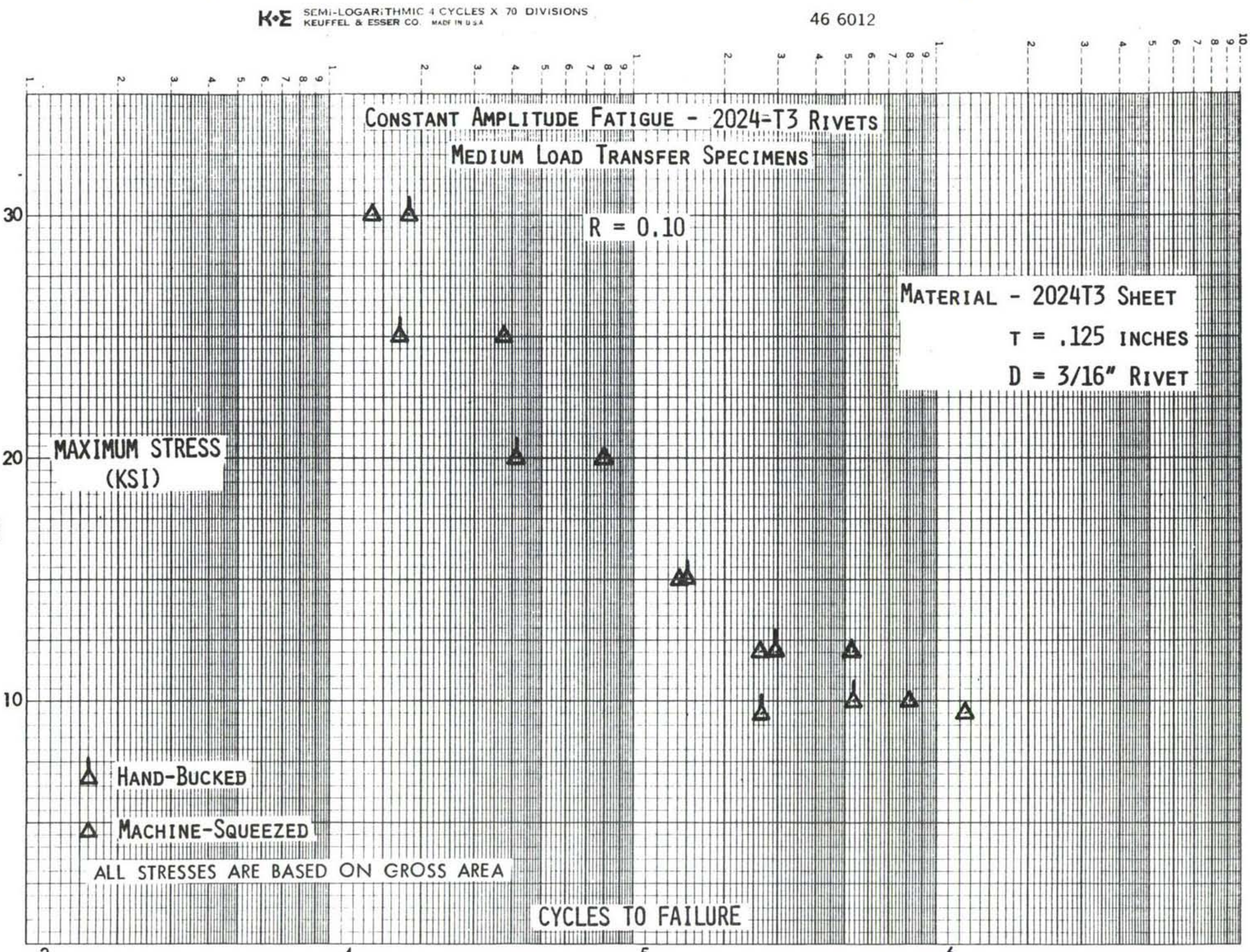

K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6012
CONSTANT AMPLITUDE FATIGUE - 2024-T3 RIVETS
MEDIUM LOAD TRANSFER SPECIMENS
R = 0.10
MATERIAL - 2024T3 SHEET
T = .125 INCHES
D = 3/16" RIVET
MAXIMUM STRESS
(KSI)
30
20
10
HAND-BUCKED
MACHINE-SQUEEZED
ALL STRESSES ARE BASED ON GROSS AREA
CYCLES TO FAILURE
10^3
10^4
10^5
10^6

Figure 16.

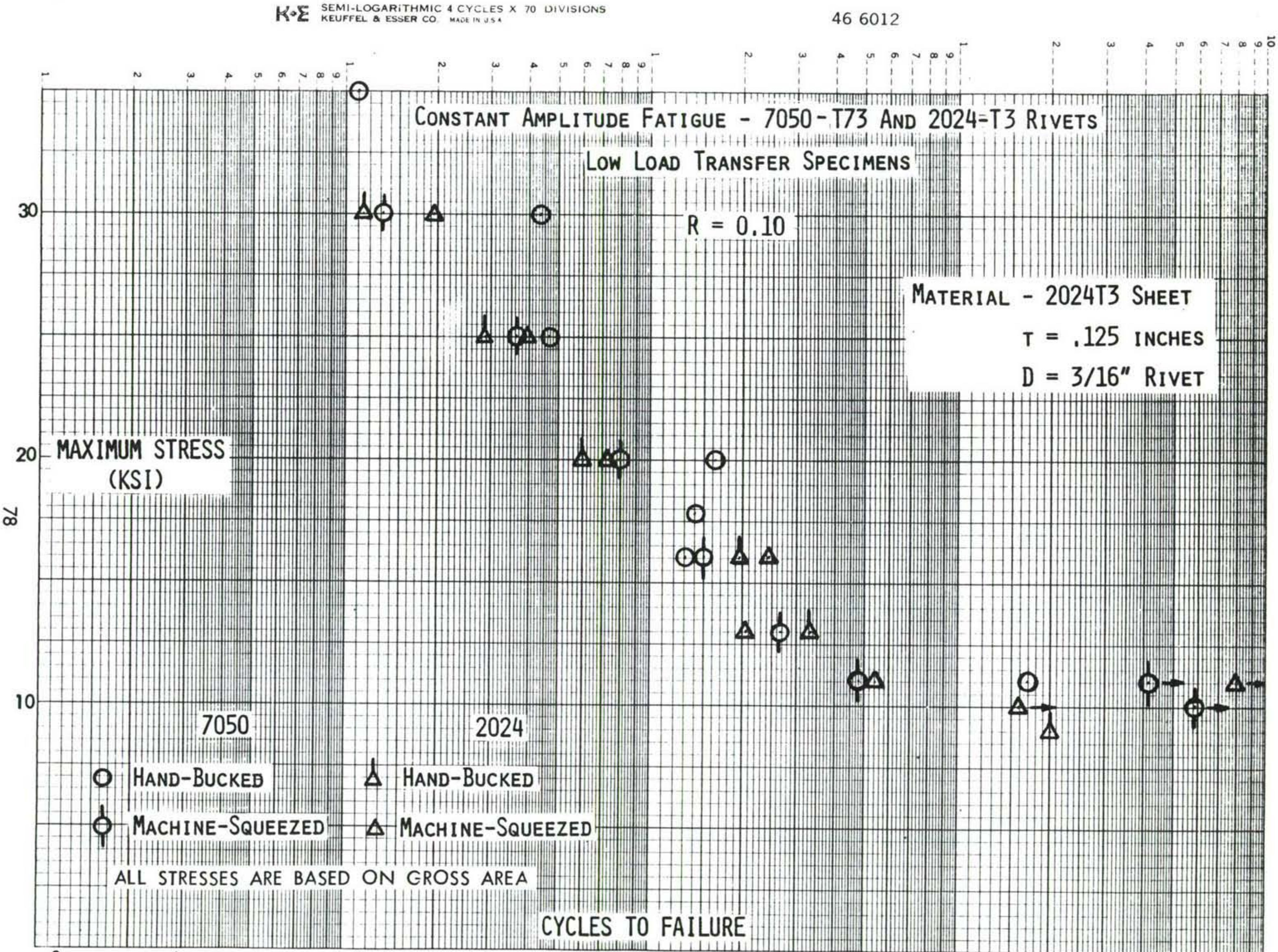
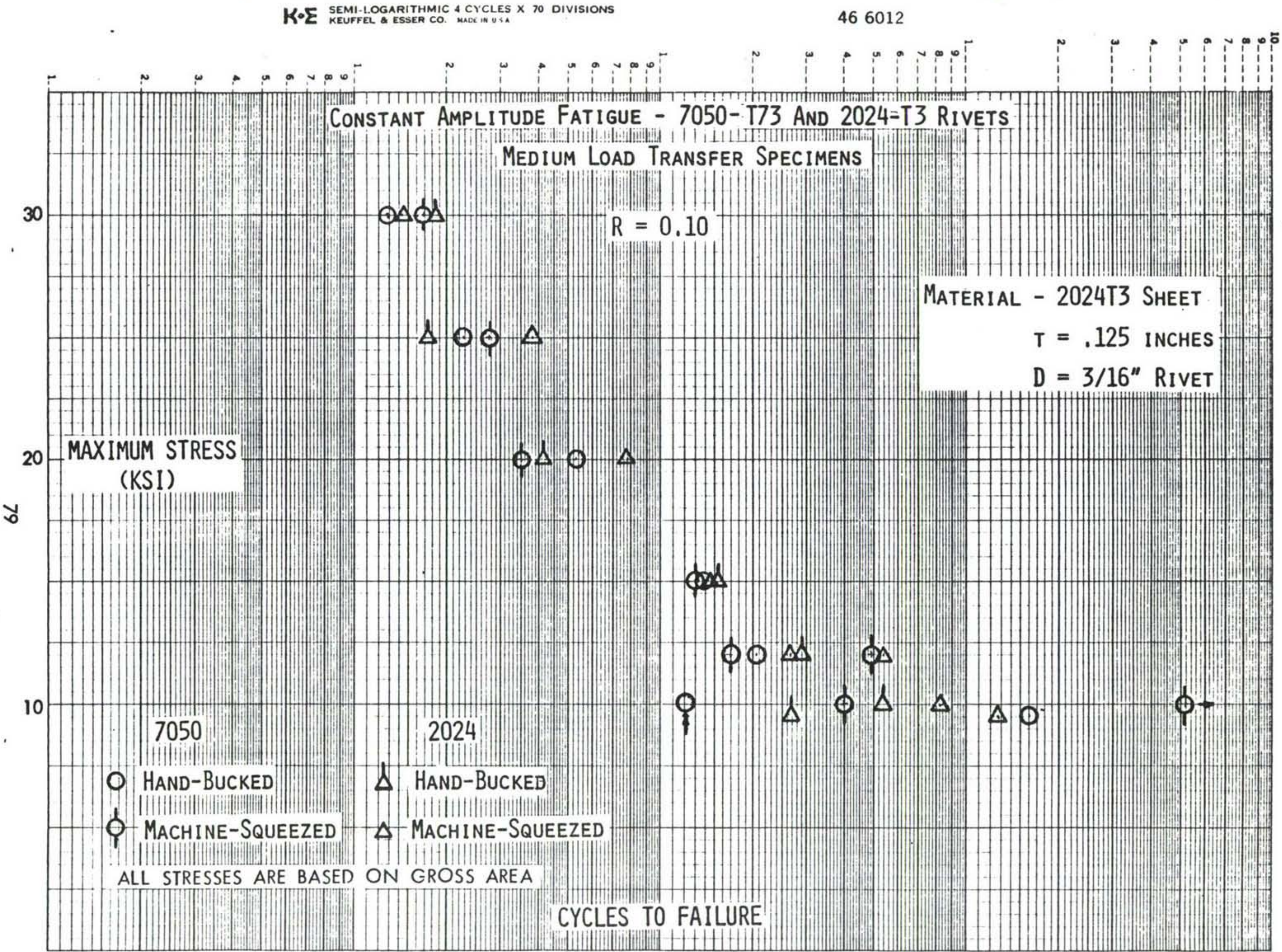

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6012
CONSTANT AMPLITUDE FATIGUE - 7050-T73 AND 2024-T3 RIVETS
LOW LOAD TRANSFER SPECIMENS
R = 0.10
MATERIAL - 2024T3 SHEET
T = .125 INCHES
D = 3/16" RIVET
MAXIMUM STRESS
(KSI)
30
20
10
7050
HAND-BUCKED
MACHINE-SQUEEZED
2024
HAND-BUCKED
MACHINE-SQUEEZED
ALL STRESSES ARE BASED ON GROSS AREA
CYCLES TO FAILURE
10^3
10^4
10^5
10^6

Figure 17.



K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6012
CONSTANT AMPLITUDE FATIGUE - 7050-T73 AND 2024-T3 RIVETS
MEDIUM LOAD TRANSFER SPECIMENS
R = 0.10
MATERIAL - 2024T3 SHEET
T = .125 INCHES
D = 3/16" RIVET
MAXIMUM STRESS
(KSI)
30
20
10
7050
HAND-BUCKED
MACHINE-SQUEEZED
2024
HAND-BUCKED
MACHINE-SQUEEZED
ALL STRESSES ARE BASED ON GROSS AREA
CYCLES TO FAILURE
10^3
10^4
10^5
10^6

Figure 18.

SECTION V. OBSERVATION AND CONCLUSIONS

Based on the tests performed under this program and the analysis of the results, the following observation and conclusion have been made:

(1) The 7050-T73 alloy rivets have developed a minimum "driven" shear strength of 43 ksi.

(2) The 7050-T73 alloy rivet installation upset characteristics, whether by hand-bucking or machine squeezing, were attained with no difficulty and with no cracking in the bucked tail after repeated blows with a rivet gun.

(3) The corrosion compatibility of the installed 7050-T73 rivet in 7075-T73 and 2024-T3 sheet materials indicate that corrosion was more severe in the bare 2024-T3 sheet with the 7050-T73 rivets than with the 2024-T31 rivets. There was no difference in the corrosion compatibility of the two rivet systems (2024-T3 and 7050-T73) when installed in sheet material coated with finishes such as MIL-C-5541 or zinc chromate.

(4) The elevated-temperature properties of 7050-T73 rivet compare favorably with the strength of 2219-T81 rivet when tested at 250^{o}F and 350^{o}F. The reduction in room-temperature strength of 7050-T73 and 2219-T81 rivets when tested at 250^{o}F is approximately 15%. The room temperature reduction, when the two systems were tested at 350^{o}F, is 42% for 7050-T73 and 38% for 2219-T81. The room-temperature strength of 7050-T73 rivets after exposure to 350^{o}F for 16 hours or more was reduced by approximately 22%.

(5) The joint fatigue strength using 7050-T73 and 2024-T31 rivets in 2024-T3 material appears to be the same. The Low Load Transfer S/N curves in Figure 17 for R = +0.10 show that the fatigue life data for both rivet systems (2024-T31 and 7050-T73) to be within the same scatter band and can be assumed equal. The medium load transfer, Figure 18, also shows the same trend. The fatigue data

indicate that the hand-bucked specimens generally, had a longer life than the machine-squeezed specimens. The conclusions are based on one diameter -3/16" and one aluminum alloy sheet material 2024-T3.

(6) The performance of the 7050-T73 rivets under the various tests and conditions make it an ideal single-rivet system. Its static and joint strength capability exceed that of 2117-T3, 2017-T31 and 2017-T3. The 7050-T73 shear strength exceeds 2024-T31 (ice box DD rivet) while the joint allowable strength can be assumed as equivalent. The elevated-temperature strength of 7050 rivets is equal to or exceeds 2219-T81 at temperatures up to 350°F and can be used efficiently in this temperature range.

SECTION VI. RECOMMENDATIONS

Based on the study and the analysis performed in this program, it is recommended that the following steps be evaluated, expedited, or implemented:

(1) The 7050 wire material in the H-13 temper should be incorporated in the QQ-A-430 material specification and the rivet strength properties added expeditiously to the standard rivet specification MIL-R-5674 to facilitate its use to the aircraft industry.

(2) The 7050-T73 rivet should be implemented and its usage encouraged and expanded to replace the currently used rivet systems and the aluminum threaded or swaged collar pins. Trade studies at various aircraft companies indicate that substantial savings can be realized by converting from the 2024-T31 DD (ice-box) rivet to the 7050-T73 rivet.

REFERENCES

1. Dewalt, W. J.; Lifka, B. W.; Nordmark, G. E.; "Rivet Qualification and Aluminum Alloy 7050," AFML-TR-76-181 Air Force Materials Laboratory, October 1976.

2. MIL-HDBK-5 Agenda item 80-22, Static Joint Strength of NAS 1097 Flush Head 7050-T73 Aluminum Alloy Solid Rivet in Clad 2024-T3 Sheet," September 4, 1981.

3. MIL-HDBK-5 Agenda item 80-23, Static Joint Strength of NAS 1097 Flush Head 7050-T73 Aluminum Alloy Solid Rivet in Clad 7075-T6 Sheet," September 4, 1981.

4. MIL-HDBK-5 Agenda item 81-35, "Static Joint Strength of MS 20426 Flush Head 7050-T73 Aluminum Alloy Solid Rivet in Clad 2024-T3 Clad Sheet."

5. MIL-HDBK-5 Agenda item 81-36, "Static Joint Strength of MS 20426 Flush Head 7050-T73 Aluminum Alloy Solid Rivet in Clad 7075-T6 Clad Sheet."

APPENDIX A

PRELIMINARY MATERIAL REQUIREMENTS

CANDIDATE 7050 MATERIAL SPECIFICATION

(Reference Briles Rivet Co. Specification BR-MS-1E)

1. SCOPE:

This specification covers the requirements for aluminum alloy 7050 rod and wire suitable for the manufacture of rivets.

2. CLASSIFICATION

2.1 Form

a. Rod

b. Wire

2.2 Temper

a. The temper of the 7050 rod and wire shall be classified as H13.

b. The definition of this temper shall be as specified in American National Standards Institute ANSI Standard H35.1.

3. REFERENCES

Except where a specific issue is indicated, the issue of the following references in effect on the date of invitation for bid shall form a part of this specification to the extent indicated herein.

a.	ANSI Std. H35.1	Alloy and Temper Designation System for Aluminum
b.	ANSI Std. 35.2	Dimensional Tolerances for Aluminum Mill Products
c.	ASTM E8	Tension Testing of Metallic Materials
d.	FED-STD-123	Marking for Domestic Shipment (Domestic Agencies)
e.	FED-STD-151	Metals; Test Methods
f.	FED-STD-184	Identification Marking of Aluminum, Magnesium, and Titanium
g.	MIL-H-6088	Heat Treatment of Aluminum Alloys
h.	MIL-STD-649	Aluminum and Magnesium Products; Preparation for Shipment and Storage.
i.	ASTM B557	Tension Testing of wrought and cast Aluminum and Magnesium Alloy products.
j.	MIL-STD-1312	Fasteners, Test Methods

4. CHEMICAL COMPOSITION

The chemical composition of the wire and rod shall conform to the requirements specified in Table 1.

TABLE 1

CHEMICAL COMPOSITION

ELEMENT	WEIGHT PERCENT MINIMUM	WEIGHT PERCENT MAXIMUM
Silicon		0.12
Iron		0.15
Copper	2.0	2.6
Manganese		0.10
Magnesium	1.9	2.6
Chromium		0.04
Zinc	5.7	6.7
Titanium		0.06
Zirconium	0.08	0.15
Others, each		0.05
Others, Total		0.15
Aluminum	Remainder	

4.1 Chemical Analysis

Chemical analysis shall be made by the wet chemical method in accordance with FED-STD-151, Method 111 or by the spectrochemical method in accordance with FED-STD-151, Method 112. In case of dispute, the chemical analysis by wet chemical methods shall be the basis for acceptance. At least one sample shall be taken for each group of ingots poured simultaneously from the same source of metal by the producer and analyzed to determine conformance to Table 1. Ingots not conforming to the requirements of this specification shall be rejected.

Analysis shall be made only for the elements specifically mentioned in the above table. If, however, the presence of other elements is indicated in the course of the analysis, further analysis shall be made to determine that these other elements are not present in excess of the limits specified.

5. **MECHANICAL PROPERTIES**

a. The tensile strength of the as-supplied 7050-H13 wire shall be within 36,000 to 46,000 psi range.

b. In addition, the mechanical properties of the wire shall conform to Table II after solution heat treatment and double aging.

TABLE II

MECHANICAL PROPERTIES OF 7050-T73 (HEAT TREATED 1/) ROD AND WIRE

PROPERTY 2/	MINIMUM	MAXIMUM
Tensile strength, psi 3/	70,000	
Yield strength, 0.2 percent offset, psi	62,000	
Elongation, percent in 4D	10.0	
Shear strength, psi	41,000	46,000

1/ Heat treat the product to the T73 condition in accordance with MIL-H-6088 and as follows:

Solution Treatment: 890° $\pm$ 10°F, 30 minutes minimum, cold water quench (100 F max.)

Double Aging: 250° $\pm$ 5°F, 4 hours minimum, followed by 355° $\pm$ 5°F, 8 hours minimum.

2/ For material 0.063 to 1.000 inch in diameter.

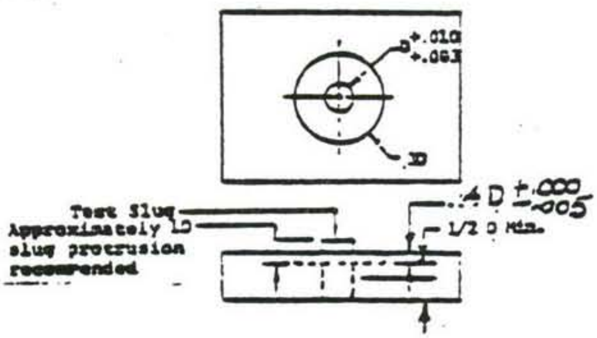
3/ Specimens for tensile testing shall conform to the requirements of ASTM E8. When practical, the material should be tested in full section, the standard round-type specimen in the largest size practical shall be used. For material having a nominal weight of less than 1 pound per lineal foot, one tension-test sample shall be selected from each lot weighing 1000 pounds or less; from lots weighing more than 1000 pounds, one additional sample shall be taken for each 1000 pounds or fraction thereof in excess of the first 1000 pounds. For material having a nominal weight of one pound or more per lineal foot, one tension-test sample shall be taken from each lot consisting of 1000 feet or less; from lots consisting of more than 1000 feet, one additional sample shall be taken for each 1000 feet or fraction thereof in excess of the first 1000 feet. Only one tension test shall be taken from any one coil when more than one coil is available.

6. FORMABILITY

Upon heat treatment to the T73 temper, 6 minimum samples of the wire shall be upset with a minimum upset button diameter of 1.6 times the wire diameter and measured upset button height of 0.3 to 0.4 times the wire diameter without showing cracks when examined without magnification.

6.1 Formability Test

The formability test shall be made in a fixture substantially in accordance with Figure 1. The button shall be formed by driving or squeezing a test slug with a flat anvil.



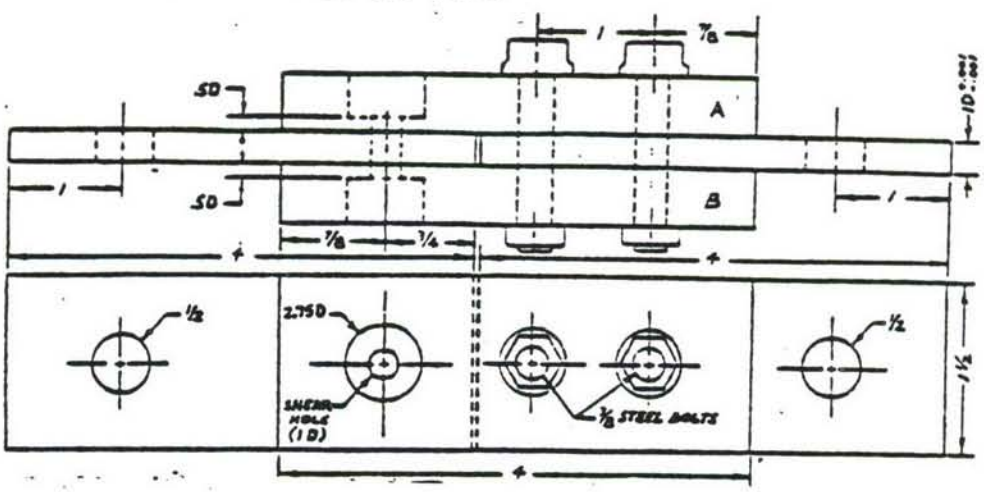
NOTE: D is the nominal wire diameter.

FORMABILITY JIG

Figure 1

7. SHEAR TEST

The shear test shall be made in a jig substantially in accordance with Figure 2. The shear strength of the wire shall be calculated on the actual measured diameter of the wire.



NOTE: Thickness of Plates A and B: 1/2 for Wire of 3/16 to 3/8 Inch Diameter
1/4 for Wire less than 3/16 Inch Diameter

DOUBLE SHEAR TEST JIG: Figure 2

8. <u>TOLERANCES</u>

Microsection examination of the wire to determine depth of local or general intergranular corrosion shall not exceed .001" as supplied and .003 after heat treatment per paragraph 5.b, Note 1/. The tolerances shall not exceed those specified in ANSI Standard H35.2 for straightness, specified length, and diameter of rod and wire.

9. <u>WORKMANSHIP</u>

The rods and wire shall be uniform in quality and condition; clean, sound, smooth, and free from hard spots, pipes, laps, cracks, kinks, seams, damaged ends, and other injurious defects within the limits consistent with best commercial practice. Discoloration due to thermal treatment shall not be cause for rejection.

10. <u>SUPPLIER QUALITY CONTROL</u>

The supplier shall furnish a report certifying conformance with the sampling, testing, and material requirements of this specification.

11. <u>VISUAL AND DIMENSIONAL QUALITY CONTROL</u>

Each lot of wire shall be examined to determine conformance with respect to workmanship and material identification. Dimensional inspections shall be made at planned intervals to ensure conformance with ANSI Standard H35.2.

12. <u>MATERIAL IDENTIFICATION</u>

Mark the material in accordance with FED-STD-184. The marking shall include this specification number (with current revision letter), alloy and temper designation, lot number, and manufacturer's identification.

13. <u>PACKAGING AND MARKING</u>

Preserve, package, mark, and pack in accordance with MIL-STD-649, Level C. Marking for shipment shall include this specification number (with the current revision letter), alloy and temper designation, wire diameter, lot number, and manufacturer's identification.

14. <u>EXCEPTIONS TO SPECIFICATION</u>

Exceptions and or deviations to the requirements of this specification must be defined by individual purchase order issued by the procuring activity and acknowledged by the supplier.

NOTE: A lot shall consist of an identified quantity of rod and wire of the same alloy, temper, and size traceable to a solution heat-treat and chemistry lot and subjected to inspection at one time.

APPENDIX B

PROCESS PROCEDURE

7050 Aluminum Alloy Rivet Heat Treat

(Reference Briles Rivet Co. Process Specification BPP-10E)

1. **SCOPE:**

This document shall prescribe the equipment and procedures utilized in heat treating 7050 aluminum alloy rivets to the T73 Temper.

2. **PURPOSE:**

To establish control of the processes involving heat treatment of 7050 alloy and to assure quality conformance of the completed product.

3. **REFERENCES:**

3.1 The following reference documents and spcifications shall form a part of this procedure to the extent indicated herein.

a.	MIL-H-6088	Heat Treatment of Aluminum Alloys
b.	ANSI Std. H35.1	Alloy and Temper Designation System for Aluminum
c.	MIL-Std-1312	Fasteners, Test Methods
d.	FED-STD-184	Identification, Aluminum Alloys
e.	BR-MS-IE	Briles Material Specification
f.	BRS-R-131	Requirement for Solid Rivets

4. **FURNACE:**

4.1 The furnace shall include a heated airflow chamber and continuous conveyor belt designed to control temperature and time prior to dropping parts directly into a quench tank.

5. **QUENCH TANK:**

5.1 A recirculating, temperature controlled quench tank equipped with a conveyorized extractor and water as the quench medium shall be utilized.

6. **DRYER:**

6.1 Conveyor or rotary extraction equipment capable of removing residual quench moisture shall be employed.

7. **OVENS:**

7.1 batch ovens suitable for uniform temperature control of various size loads shall be used.

8. **CLEANING EQUIPMENT:**

8.1 The cleaning equipment shall include a vapor degreaser, hot (soap solution) centrifuge, chemical cleaning and rinse tanks.

9. **HEAT TREATMENT: General Procedure**

9.1 Heat treatment procedures in accordance with MIL-H-6088, BR-MS-IE, and paragraph 10 through 15 herein.

10. **HEAT TREATMENT: Specific Procedure (Utilize at Voi-Shan, Redondo Beach Facility)**

10.1 Degrease and chemically clean rivets prior to heat treat per paragraph 11.

10.2 Use conveyor furnace #6, set point at 895° F, allow to stabilize on recording chart, 4 min. per ft. belt speed.

10.3 Spread rivets on the conveyor belt uniformly to a maximum 1" thickness.

10.4 Heat treat rivets 44/45 minutes total time as measured from when rivets enter heat chamber until they drop into quench water. This cycle will result in 32/33 minutes at 895° F $\pm$ 5° F temperature (allows 12 minutes, required to reach temperature in accordance with thermocouple survey).

10.5 Rapid quench in 50°/80° F water. Allow 10 minutes minimum time interval between batches to prevent mixing rivet diameters and/or lengths.

10.6 Hot air dry 150° F maximum, conveyor oven or centrifuge and restore in clean properly identified containers.

10.7 Shear test, 4 pcs. selected at random. 3 KSI maximum variation is acceptable within a solution treat lot. (Shear value is not critical at this stage, only variation).

11. **DEGREASE AND CLEAN: Prior to Heat Treat**

11.1 Procedure to remove oil, grease, wax, etc. and chemically clean rivets.

11.2 Vapor degrease thoroughly in Perchlor. or Trichlor. hot vapor degreasing tank.

11.3 An alternate hot, 160°/180° F soapy solution, (borax base soap) rinse and spin dry degreasing method may be used.

Mild alkaline clean, (dip tank) rinse, desmutt (deoxidizier dip tank) hot rinse and spin dry. Restore in properly identified clean containers for heat treat.

12. DOUBLE AGING CYCLE:

12.1 Age 4 hours at 250° F ± 5° F. Heat up time must be added to allow 4 hours net at 250° F. Distribute rivets and containers to produce uniform temperature throughout load. The delay time after solution treat, prior to the first aging cycle is not critical and may vary for manufacturing convenience.

12.2 Second aging cycle: Age 8 hours at 355° F ± 5° F. Option: May start immediately after first age or delay. Timing is not critical. Remove 4 piece sample, including wire specimen for shear and tensile testing per BPS-R-131.

12.3 Check shear values, 42/47 KSI tolerance, use single shear test fixture and method per MIL-STD-1312 Test 20.

12.4 Remove rivet lots that are within 42/47 KSI shear from oven. Additional time at 355° F is required for any lots exceeding 47 KSI shear. Check shear value every hour beyond 8 hours until acceptable or until 16 hours maximum time at 355% F has elapsed. (Note: most wire samples will be within shear 42/47 and tensile, 70,000 minimum after 8 hours).

12.5 Rivets not within 42/47 KSI shear after second aging cycle may be re-heat treated and aged beginning with 10.2 and repeating cycle. Note: Re-heat treated lots must not exceed intergranular corrosion limits as defined in 13.

13. INTERGRANULAR CORROSION:

Intergranular corrosion may not exceed .003 when subjected to heat treatment, mounted and microsection examined under 100X minimum magnification.

14. FORMABILITY:

14.1 Final acceptance of a heat treat lot shall be formability. When heat treated to the T73 Temper, the rivets shall be capable of being upset with a minimum bucktail diameter of 1.6d and .3d to .4d height per BPS-R-131 without developing cracks when examined by eye.

15. EXCEPTIONS:

15.1 Exceptions and/or deviations to the requirements outlined in this document must be defined and approved by BRILES RIVET CORPORATION and acknowledged by effected activities prior to incorporation and/or use.

NOTE: This draft dated June 1981, prepared by the Engineering Specifications and Standards Department, Naval Air Engineering Center, has not been approved and is subject to modification. DO NOT USE FOR PROCUREMENT PURPOSES. (Project No. 9525-0067)

QQ-A-430B
Amendment-3

SUPERSEDING
AMENDMENT 2
22 May 1978

FEDERAL SPECIFICATION

ALUMINUM ALLOY ROD AND WIRE; FOR RIVETS AND COLD HEADING

This amendment which forms a part of Federal Specification QQ-A-430B, dated 21 May 1970, was approved by the Commisioner, Federal Supply Service, General Services Administration, for the use of all Federal Agencies.

Page 1

1.2.1: Delete list containing alloys and tempers and substitute:

1100-0, H14, H24	3003-0, H14, H24	7075-0, H13, H23
2017-0, H13, H23	5005-0, H22, H32	7178-0, H13, H23
2024-0, H13, H23	5056-0, H22, H32	
2117-0, H13, H23	6053-0, H13, H23	
2117- , H15, H25	6061-0, H13, H23	
2219-0, H13, H23	7050- H13	

Page 4

Table I. Add the following alloys and chemical compositions:

"Alloy	Silicon	Iron	Copper	Manganese	Magnesium
2219	0.20	0.30	5.8 to 6.8	0.20 to 0.40	0.02
6053	3/	0.35	0.10	- - -	1.1 to 1.4
7050	0.12	0.15	2.0 to 2.6	0.10	1.9 to 2.6
7178	0.40	0.50	1.6 to 2.4	0.30	2.4 to 3.1

Chromium	Zinc	Titanium	Others Each	Others Total	Aluminum
- - -	0.10	0.02 to 0.10	0.05 2/	0.15	Remainder
0.15 to 0.35	0.10	- - -	0.05	0.15	Remainder
0.04	5.7 to 6.7	0.06	0.05 4/	0.15	Remainder
0.18 to 0.35	6.3 to 7.3	0.20	0.05	0.15	Remainder

2/ Vanadium 0.05 to 0.15; Zirconium 0.10 to 0.25.

3/ Silicon 45 to 65 percent of Magnesium content.

4/ Zirconium 0.08 to 0.15"

FSC 9525
9530

Page 5

Table II: In the "Alloy and temper" column

delete	and substitute
"1100-H14	1100-H14, H24
2017-H13	2017-H13, H23
2024-H13	2024-H13, H23
2117-H13	2117-H13, H23
2117-H15	2117-H15, H25
3003-H14	3003-H14, H24
5005-H32	5005-H22, H32
5052-H32	5052-H22, H32
5056-H32	5056-H22, H32
6061-H13	6061-H13, H23
7075-H13	7075-H13, H23"

Table II: Add the following alloys and tensile properties:

"Alloy and temper	Diameter, inches	Tensile strength, psi Minimum	Tensile strength, psi Maximum
2219-H13, H23	Up thru 1.000	28,000	38,000
6053-0	Up thru 1.000	-	19,000
6053-H13, H23	Up thru 1.000	19,000	26,000
7050-H13	Up thru 1.000	36,000	46,000"

Page 6

Table III: Add the following alloys and tensile properties:

"Alloy and temper	Diameter inches	Tensile strength psi, min.	Yield strength 1/ psi, min.
2219-T81	0.063 to 1.000	58,000	40,000
6053-T61	0.063 to 1.000	30,000	20,000
7050-T73	0.063 to 1.000	70,000	62,000
7178-T6	0.063 to 1.000	84,000	73,000

Elongation 1/ in 2 inches or 4D 2/ percent, min.	Shear strength 3/ psi, min.	psi, max.
6	32,000	-
14	20,000	-
7	41,000	46,000
5	46,000"	

Page 7 and 8

4.2.2.2: Delete and substitute:

"4.2.2.2 Finish product analysis. When compliance with 4.2.2.1 cannot be established, samples shall be selected as follows: From material having a nominal weight of less than one pound per lineal foot, one sample shall be selected from each lot weighting 1,000 pounds or less; from lots weighing more than 1,000 pounds, one additional sample shall be taken for each 1,000 pounds or fraction thereof in excess of the first 1,000 pounds. From material having a nominal weight of one pound or more per lineal foot, one sample shall be taken from each lot consisting of 1,000 feet, or less; from lots consisting of more than 1,000 feet, one additional sample shall be taken for each 1,000 feet or fraction thereof in excess of the first 1,000 feet. Only one sample shall be taken from any one piece when more than one piece is available. Not more than one analysis shall be required per piece."

4.2.3.1: Delete and substitute:

"4.2.3.1 Number of test samples in temper supplied. From material having a nominal weight of less than one pound per lineal foot, one tension-test sample shall be selected from each lot weighting 1,000 pounds, or less; from lots weighing more than 1,000 pounds, one additional sample shall be taken for each 1,000 pounds or fraction thereof in excess of the first 1,000 pounds. For material having a weight of one pound or more per lineal foot, one tension-test sample shall be taken from each lot consisting of 1,000 feet, or less; from lots consisting of more than 1,000 feet, one additional sample shall be taken for each 1,000 feet or fraction thereof in excess of the first 1,000 feet. Only one tension test shall be taken from any one piece when more than one piece is available."

MILITARY INTEREST:
Custodians:
Navy - AS
Air Force - 11

Review activities:
Army - AV, MR, MI, EA, AR
Navy - AS
Air Force - 99
DLA - IS

User activities:
Army - ME

CIVIL AGENCY COORDINATING ACTIVITIES:
GSA-FSS

PREPARING ACTIVITY:
Navy - AS

Project No. 9525-0067

QQ-A-430B
May 21, 1970
SUPERSEDING
Fed. Spec. QQ-A-430A
March 28, 1967

FEDERAL SPECIFICATION

ALUMINUM ALLOY ROD AND WIRE; FOR RIVETS AND COLD HEADING

This specification was approved by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal agencies.

1. SCOPE AND CLASSIFICATION

1.1 Scope. Aluminum alloy wire and rod covered by this specification are suitable for the manufacture of rivets and other utility items by cold die-heading operations.

1.2 Classification.

1.2.1 Alloys and tempers. Wire and rod shall be furnished in one of the following alloys and tempers, as specified (see 6.1):

1100-0
1100-H14
2017-0
2017-H13
2024-0
2024-H13
2117-0
2117-H13
2117-H15
3003-0
3003-H14
5005-0
5005-H32
5052-0
5052-H32
5056-0
5056-H32
6061-0
6061-H13
7075-0
7075-H13

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issues in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

FSC 9525
9530

Federal Standards:

Fed. Std. No. 123 - Marking for Domestic Shipment (Civilian Agencies).

Fed. Test Method Std. No. 151 - Metals; Test Methods.

Fed. Std. No. 184 - Identification Marking of Aluminum, Magnesium, and Titanium.

Fed. Std. No. 245 - Tolerances for Aluminum Alloy and Magnesium Alloy Wrought Products.

(Activities outside the Federal Government may obtain copies of Federal Specifications, Standards, and Handbooks as outlined under General Information in the Index of Federal Specifications and Standards and at the prices indicated in the Index. The Index, which includes cumulative monthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

(Single copies of this specification and other Federal Specifications required by activities outside the Federal Government for bidding purposes are available without charge from Business Service Centers at the General Services Administration Regional Offices in Boston, New York, Washington, D.C., Atlanta, Chicago, Kansas City, Mo., Fort Worth, Denver, San Francisco, Los Angeles and Seattle, Washington.

(Federal Government activities may obtain copies of Federal Specifications, Standards, and Handbooks and the Index of Federal Specifications and Standards from established distribution points in their agencies,)

Military Specification:

MIL-H-6088 - Heat Treatment of Aluminum Alloys, Process of.

Military Standards:

MIL-STD-129 - Marking for Shipment and Storage.

MIL-STD-649 - Aluminum and Magnesium Products, Preparation for Shipment and Storage.

(Copies of Military Specifications and Standards required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless a specific issue is identified, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials (ASTM) Standard:

E8-66 Tension Testing of Metallic Materials

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania, 19103.)

3. REQUIREMENTS

3.1 Suitability for cold heading. The wire shall be such that cold-headed shapes may be produced therefrom in accordance with the requirements of the applicable product specification.

3.2 Chemical composition.

3.2.1 The chemical composition of the wire and rod shall conform to the requirements specified in table I.

3.3 Mechanical Properties.

3.3.1 Tensile properties of material as supplied. The tensile properties in the direction of rolling or drawing shall conform to the requirements of table II.

3.3.2 Tensile properties after heat treatment. In addition to the requirements of 3.3.1, the mechanical properties in the direction of rolling or drawing of heat-treatable material ordered in the annealed or strain hardened tempers and subsequently solution heat treated (T4 temper) or solution heat treated and artificially aged (T6 temper) shall conform to the requirements of table III for either the tensile requirements or the shearing requirements.

3.4 Tolerances. The tolerances shall not exceed those specified in FED-STD-245 for straightness, specified length, and diameter of rod and wire.

3.5 Marking for identification. Unless otherwise specified (see 6.1), wire or rod shall be marked in accordance with FED-STD-184.

3.6 Material in sizes not covered in this specification. Mechanical properties and tolerances of material falling outside the diameter limits (see tables II and III) covered in this specification shall be as specified.

TABLE I. Chemical requirements elements.
(Percent maximum unless shown as a range)

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Others		Aluminum, min.
									Each	Total 1/	
1100	1.0Si+Fe		0.05 to 0.20	0.05	---	---	0.10	---	0.05	0.15	99.00
2017	0.8	0.7	3.5 to 4.5	0.40 to 1.0	0.20 to 0.8	0.10	0.25	---	0.05	0.15	Remainder
2024	0.50	0.50	3.8 to 4.9	0.30 to 0.9	1.2 to 1.8	0.10	0.25	---	0.05	0.15	Remainder
2117	0.8	0.7	2.2 to 3.0	0.20	0.20 to 0.50	0.10	0.25	---	0.05	0.15	Remainder
3003	0.6	0.7	0.05 to 0.20	1.0 to 1.5	---	---	0.10	---	0.05	0.15	Remainder
5005	0.4	0.7	0.20	0.20	0.50 to 1.1	0.10	0.25	---	0.05	0.15	Remainder
5052	0.45Si+Fe		0.10	0.10	2.2 to 2.8	0.15 to 0.35	0.10	---	0.05	0.15	Remainder
5056	0.30	0.40	0.10	0.05 to 0.20	4.5 to 5.6	0.05 to 0.20	0.10	---	0.05	0.15	Remainder
6061	0.40-0.8	0.7	0.15 to 0.40	0.15	0.8 to 1.2	0.04 to 0.35	0.25	0.15	0.05	0.15	Remainder
7075	0.40	0.50	1.2 to 2.0	0.30	2.1 to 2.9	0.18 to 0.35	5.1 to 6.1	0.20	0.05	0.15	Remainder

1/ Analysis shall be made regularly only for the elements specifically mentioned in the table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine conformance with the limits specified for other elements.

TABLE II. Tensile properties.

Alloy and temper	Diameter, Inches	Tensile strength, p.s.i.	
		Minimum	Maximum
1100-0	Up thru 1.000	---	15,500
1100-H14	Up thru 1.000	16,000	21,000
2017-0	Up thru 1.000	---	35,000
2017-H13	Up thru 1.000	30,000	40,000
2024-0	Up thru 1.000	---	35,000
2024-H13	Up thru 1.000	32,000	42,000
2117-0	Up thru 1.000	---	25,000
2117-H13	0.616 thru 1.000	25,000	32,000
2117-H15	Up thru 0.615	28,000	35,000
3003-0	Up thru 1.000	---	19,000
3003-H14	Up thru 1.000	20,000	26,000
5005-0	Up thru 1.000	---	20,000
5005-H32	Up thru 1.000	17,000	23,000
5052-0	Up thru 1.000	---	32,000
5052-H32	Up thru 1.000	31,000	37,000
5056-0	Up thru 1.000	---	46,000
5056-H32	Up thru 1.000	44,000	52,000
6061-0	Up thru 1.000	---	22,000
6061-H13	Up thru 1.000	22,000	30,000
7075-0	Up thru 1.000	---	40,000
7075-H13	Up thru 1.000	36,000	46,000

TABLE III. Tensile properties after heat treatment.

Alloy and Temper	Diameter, inches	Tensile strength p.s.i., min.	Yield strength (1) at 0.2 percent offset p.s.i., min.	Elongation 1/ in 2 inches or 4D 2/ percent min.	Shear strength 3/ p.s.i., min.
2017-T4	0.063 to 1.000	55,000	32,000	12	33,000
2024-T4	.063 to 1.000	62,000	40,000	10	37,000
2117-T4	.063 to 1.000	38,000	18,000	18	26,000
6061-T6	.063 to 1.000	42,000	35,000	10	25,000
7075-T6	.063 to 1.000	77,000	66,000	7	42,000

1/ The measurement of elongation and yield strength is not required for wire less than 0.125 inch diameter.

2/ "D" represents specimen diameter.

3/ Shear strength applicable for finished rivets in lieu of tensile tests.

3.7 Heat treatment. To check conformance to 3.3.2, the samples selected in accordance with 4.2.3.2 shall be heat treated in accordance with the requirements of MIL-H-6088.

3.8 Workmanship. The rods and wire shall be uniform in quality and condition; clean, sound, smooth, and free from hard spots, pipes, laps, cracks, kinks, seams, damaged ends, and other injurious defects within the limits consistent with best commercial practice. Discoloration due to thermal treatment shall not be cause for rejection.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Sampling.

4.2.1 Lot. A lot shall consist of an identified quantity of rod and wire of the same alloy, temper and size traceable to a heat treat lot or lots and subjected to inspection at one time.

4.2.2 Sampling for chemical analysis.

4.2.2.1 Ingot sampling. At least one sample shall be taken for each group of ingots of the same alloy poured simultaneously from the same source of molten metal by the producer and analyzed to determine conformance to 3.2 (see 4.4.1). Ingots not conforming to the requirements of this specification shall be rejected. Complete ingot analysis records shall be available at the producer's plant to the Government.

4.2.2.2 Finish product analysis. When compliance with 4.2.2.1 cannot be established, samples shall be selected as follows: From material having a nominal weight of less than one pound per lineal foot, one sample shall be selected from each lot weighing 500 pounds or less; from lots weighing more than 500 pounds, one additional sample shall be taken for each 1,000 pounds or fraction thereof in excess of the first 500 pounds. From material having a nominal weight of one pound or more per lineal foot, one sample shall be taken from each lot consisting of 500 feet, or less; from lots consisting of more than 500 feet, one additional sample shall be taken for each 1,000 feet or fraction thereof in excess of the first 500

feet. Only one sample shall be taken from any one piece when more than one piece is available. Not more than one analysis shall be required per piece.

4.2.3 Samples for mechanical property tests.

4.2.3.1 Number of test samples in temper supplied. From material having a nominal weight of less than 1 pound per lineal foot, one tension-test sample shall be selected from each lot weighing 500 pounds, or less; from lots weighing more than 500 pounds, one additional sample shall be taken for each 1,000 pounds or fraction thereof in excess of the first 500 pounds. For material having a nominal weight of 1 pound or more per lineal foot, one tension-test sample shall be taken from each lot consisting of 500 feet, or less; from lots consisting of more than 500 feet, one additional sample shall be taken for each 1,000 feet or fraction thereof in excess of the first 500 feet.

4.2.3.2 Number of tests after heat treatment. From heat treatable material ordered in the annealed (0) temper or strain hardened (H) temper an additional number of specimens equal to those required by 4.2.3.1 shall be taken and tested after solution heat treatment, or after solution heat treatment and artificial aging, to determine compliance with 3.3.2. At the discretion of the contractor either the tensile or the shear test shall be performed but both tests are not required. However, the material shall be capable of meeting both the tensile properties and shear strengths shown in Table III.

4.2.4 Sampling for visual and dimensional examination. Each rod and wire shall be examined to determine conformance to this specification with respect to workmanship and identification marking. Examinations for dimensions shall be made at planned intervals to insure conformance to the tolerances specified. On approval of the procuring activity, a system of statistical quality control may be used for dimensional, marking, and workmanship examination.

4.3 Examination.

4.3.1 Visual and dimensional examination. Each sample rod and wire selected in accordance with 4.2.4 shall be visually examined and measured to verify conformance with the specification.

4.3.2 Preservation, packaging, packing, and marking for shipment. The preservation, packaging, packing, and marking for shipment shall be examined to determine compliance with the requirements of section 5.

4.4 Test methods.

4.4.1 Chemical analysis. Chemical analysis shall be made by the wet chemical method in accordance with method 111 of Fed. Test Method Std. No. 151

or by the spectrochemical method in accordance with method 112 of Fed. Test Method Std. No. 151. In case of dispute, the chemical analysis by wet chemical methods shall be the basis for acceptance.

4.4.2 Mechanical properties.

4.4.2.1 Types of specimens and test method. Specimens for tensile testing shall conform to the requirements of method 211 of Fed. Test Method Std. No. 151 (ASTM E 8-66). When practicable, the material should be tested in full section. For material which is not tested in full section, the standard round type specimen in the largest size practicable shall be used.

4.4.2.2 Shear test. When performed, shear test shall be made in a jig substantially in accordance with figure 1. Other types of shearing jigs may be used upon approval of the procuring activity. The shearing strength of the wire shall be calculated on the actual measured diameter of the wire.

4.5 Rejection and retest. Failure of a specimen to meet the test requirements shall be cause for rejection of the lot. At the discretion of the contractor-supplier, retest will be permitted. A retest sample of five specimens shall be tested to replace each failed specimen of the original sample. If one of the retest specimens fail, the lot shall be rejected with no further retesting permitted.

5. PREPARATION FOR DELIVERY

5.1 Preservation, packaging, and packing. All rod and wire shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-649. Unless otherwise specified (see 6.1), material shall be preserved, packaged, and packed in accordance with level C.

5.2 Marking for shipment.

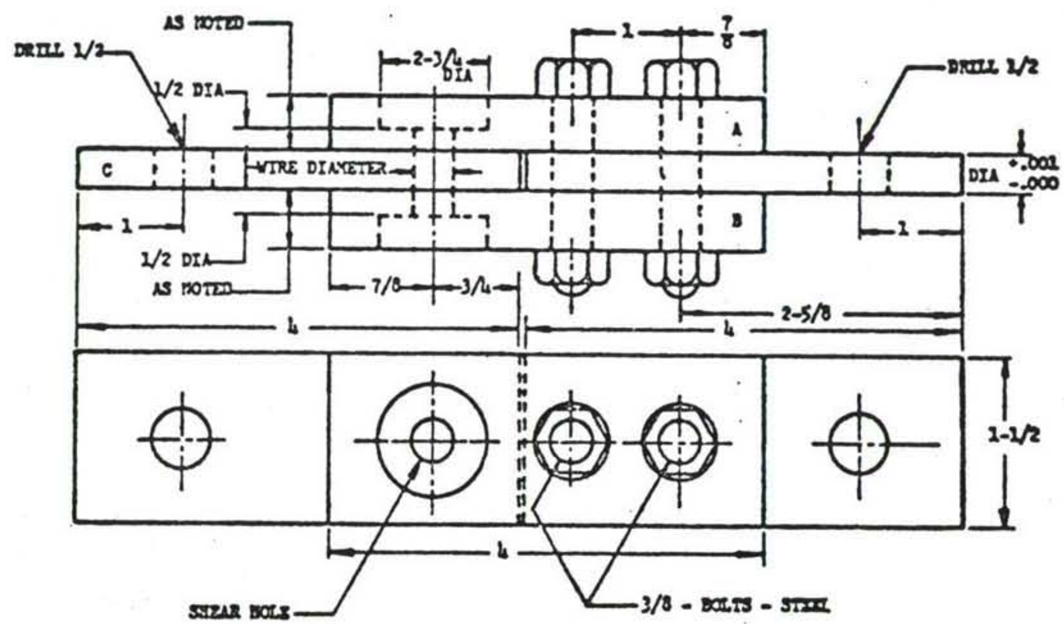
5.2.1 Civil agencies. Marking for shipment shall be in accordance with Fed. Std. No. 123. Special marking shall be as specified (see 6.1).

5.2.2 Military agencies. Shipping containers shall be marked in accordance with MIL-STD-129. Special marking shall be as specified (see 6.1).

6. NOTES

6.1 Order data. Purchasers should select the preferred options permitted herein and include the following information in procurement documents:

(a) Title, number, and date of this specification.



NOTE:-

THICKNESS OF PLATES "A" AND "B"
1/2 FOR RIVETS OF 3/16- TO 3/8-INCH DIAMETER
1/4 FOR RIVETS LESS THAN 3/16-INCH

DIA = DIAMETER OF WIRE.

Figure 1. Double shear test jig.

(b) Alloy and temper desired (see 1.2).

(c) Size required, see table II, table III and 3.6.

(d) Identification marking, if different (see 3.5).

(e) Levels of preservation, packaging and packing if different (see 5.1).

6.2 Definitions.

6.2.1 Capable of: The term "capable of" as used in this specification (see 4.2.3.2), means that the test need not be performed by the producer of the rod and wire; however, should subsequent testing by the procuring activity establish that the material does not meet these requirements, the rod and wire will be rejected.

MILITARY INTEREST:
Custodians:
Army - ME
Navy - AS
Air Force - 11

Review activities:
Army - AV, MR, MU
Navy - AS
Air Force - 84

User activities:
Army - WC
Navy - SH

Preparing activity:
Navy - AS

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 395-533 (4682)

Orders for this publication are to be placed with General Services Administration, acting as an agent for the Superintendent of Documents. See Section 2 of this specification to obtain copies and other documents referenced herein. Price 15 cents each.

MIL-R-5674D
15 December 1981
SUPERSEDING
MIL-R-5674C
25 January 1966

MILITARY SPECIFICATION

RIVETS, STRUCTURAL, ALUMINUM ALLOY, TITANIUM COLUMBIUM ALLOY, GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers aluminum alloy and titanium columbium alloy rivets.

1.2 Classification.

1.2.1 Composition and condition. The rivets shall be furnished in the following compositions and conditions:

Composition	Temper	Condition
1100	-F	As fabricated
2017	-T4	Solution heat treated
2024	-T4	Solution heat treated
2117	-T4	Solution heat treated
2219	-T81	Solution heat treated and artificially aged
5056	-H32	Strain hardened and then stabilized
7050	-T73	Solution heat treated and artificially aged
45Cb		Per AMS 4982

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, New Jersey 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 5320

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified, the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

QQ-A-430	Aluminum Alloy Rod and Wire; for Rivets and Cold Heading
PPP-H-1581	Hardware (Fasteners and Related Items) Packaging and Packing for Shipment and Storage of

Military

MIL-C-5541	Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys
MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-A-8625	Anodic Coatings, for Aluminum and Aluminum Alloys

STANDARDS

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-1312	Fasteners, Test Methods

(Copies of specifications, standards, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and supplement thereto, if applicable.

Society of Automotive Engineers

AMS 4982	Titanium Alloy Bars-45 Cb, Annealed

(Copies of Aerospace Material Specifications may be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

American Society for Testing and Materials (ASTM)

ASTM	B565	Shear Testing of Aluminum and Aluminum-Alloy Rivets and Cold-heading Wire and Rods
ASTM	E8	Tension Testing of Metallic Materials

(Applications for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3. REQUIREMENTS

3.1 Military standards. The individual item requirements shall be as specified herein and in accordance with the applicable standard. In the event of any conflict between the requirements of this specification and the standard, the latter shall govern.

3.2 Material. The rivets shall be made from material conforming to QQ-A-430 or AMS 4982, as applicable.

3.3 Design. Rivet design shall be as specified on the applicable standard.

3.4 Shear strength. The undriven shear strength of rivets greater than 0.0937 inch in diameter shall be as specified in table I when tested as specified in 4.5.2.1. Shear strength tests on 2017, 2024, 2117, 2219, and 7050 rivets shall be made with the rivets in the heat-treated condition (see 4.4.1).

TABLE I. Undriven shear strength.

RIVET		SHEAR STRENGTH (lb/in^2)	
Composition	Temper	Minimum	Maximum
1100	F	N/A	N/A
5056	H32	24,000	N/A
2117	T4	26,000	N/A
2219	T81	32,000	N/A
2017	T4	33,000	N/A
2024	T4	37,000	N/A
7050	T73	41,000	N/A
45Cb	Annealed	50,000	56,000

3.4.1 For rivets smaller than 0.0937 inch in diameter or for non-standard diameters for which a shear test fixture is not available, tensile test shall be made (see 4.5.2.2). The wire or rod samples shall be taken from the same material lot that the rivets are made from and heat-treated with the rivets it represents. Tensile properties shall be as specified in QQ-A-430, Table III or AMS 4982. A tensile test is not required for 1100-F and 5056-H32 aluminum alloy rivets.

3.5 Heat treatment. Heat treatment of aluminum alloy 2017-T4, 2024-T4, 2117-T4, 2219-T81, 5056-H32, and 7050-T73 rivets shall be in accordance with MIL-H-6088. Heat treatment for 45Cb rivets shall be in accordance with AMS 4982.

3.6 Coating. Aluminum alloy 1100-F, 2017-T4, 2117-T4, 2219-T81, 5056-H32 and 7050-T73 rivets shall be anodized in accordance with MIL-A-8625 or chemically surface treated in accordance with MIL-C-5541. Aluminum alloy 2024-T4 rivets shall be anodized in accordance with MIL-A-8625. The type of coating shall be as specified on the applicable standard. No coating is required on 45Cb rivets.

3.7 Roundness and concentricity. Rivet heads shall not deviate from true roundness and concentricity with the shank by an amount which will produce a full indicator movement greater than the value specified in table II for the corresponding rivet diameter. The reading shall be taken with the indicator touching the periphery of the head as the rivet is rotated with the shank as an axis.

TABLE II. Tolerances on roundness and concentricity.

Nominal diameter of rivet shank (inch)	Total variation in indicator reading on rivet head	
	Flush head (inch)	Protruding head (inch)
0.062, 0.094, 0.125	0.010	0.010
0.156, 0.187	0.010	0.015
0.250	0.010	0.020
0.312, 0.375	0.015	0.020

3.8 Discontinuities. Rivets shall be cold formed or forged to conform to the requirements of table III. The rivets shall be free from surface discontinuities except that:

a. Indented circles or arc lines concentric to the shank diameter, not greater than 0.004 inches in depth, are acceptable.

b. Smooth irregularities at the periphery of the head that do not extend inside the minimum head diameter, as defined on the applicable standard, are acceptable. No material separation is permitted.

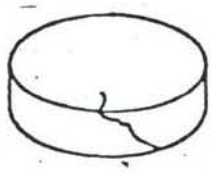
TABLE III. Discontinuities.

Location	Permissible Condition	Maximum Depth Normal to Surface (1/)
Top of Head	Laps, seams, die marks, etch pits and minor isolated inclusions	Up to .2500 dia .004 .2812 and .3125 dia. .006 .3437 and .3750 dia. .007
Shank and Bearing Area of Head	Isolated nicks, abrasions, etch pits, minor isolated inclusions, intergranular corrosion laps, seams die marks, fins, etc.	0.004
	Continuous longitudinal defects	0.002

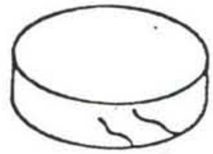
1/ Measured perpendicular to a line tangent to the curved surface at the point of intersection with the discontinuity.

3.9 Driveability. Aluminum alloy 7050 rivets shall have a bucked head not less than 1.6 times the rivet diameter. Rivets of all other alloys shall have a bucked head diameter of not less than 1.4 times the rivet diameter. The bucked head height shall not be less than 0.3 times the rivet diameter.

3.9.1 Cracks. Rivets made of alloys 1100-F, 2117-T4, 5056-H32, 7050-T73 and 45Cb shall show no cracks when visually inspected. Aluminum alloy 2017-T4, 2024-T4, and 2219-T81 rivets shall meet the requirements of figure 1.

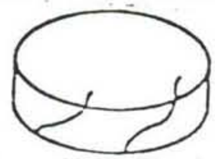


Acceptable provided cracks do not extend within a circle concentric with and having a diameter approximately 1.1 times the shank diameter.

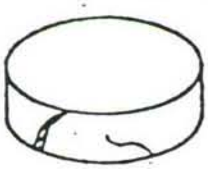


Acceptable provided cracks do not extend within a circle concentric with and having a diameter approximately 1.1 times the shank diameter.

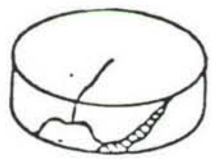
Acceptable provided cracks do not extend within a circle concentric with and having a diameter approximately 1.1 times the shank diameter and provided the cracks do not tend to intersect so as to be a potential cause of a section of the head chipping out.



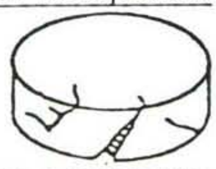
Acceptable provided cracks do not extend within a circle concentric with and having a diameter approximately 1.1 times the shank diameter and provided the cracks do not tend to intersect so as to be a potential cause of a section of the head chipping out.



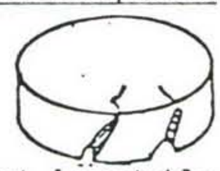
Not Acceptable.



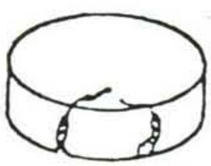
Not Acceptable.



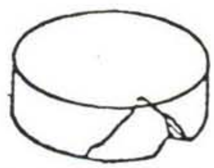
Not Acceptable.



Not Acceptable.



Not Acceptable.



Not Acceptable.

FIGURE 1. Cracks.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of inspections. All of the examinations and tests specified herein are classified as quality conformance inspections.

4.3 Sampling.

4.3.1 Sampling for material acceptance. Sampling, inspection, and testing of the wire or rod from which the rivets are manufactured shall be in accordance with QQ-A-430 or AMS 4982.

4.3.2 Sampling for end item acceptance.

4.3.2.1 Inspection lot. An inspection lot shall consist of rivets of the same alloy, condition, temper, diameter, and form. The rivets shall be manufactured and heat treated as a batch and submitted for acceptance at the same time.

4.3.2.2 Sampling for visual examination. A random sample shall be selected from each lot in accordance with MIL-STD-105, inspection level II, acceptable quality level of 4.0 percent defective.

4.3.2.3 Sampling for tests. Lot size shall be defined in terms of pounds and sampling size shall be defined in terms of number of rivets. For lots of 1,300 pounds and less, a random sample shall be selected in accordance with MIL-STD-105, inspection level S-2, acceptance quality level (AQL) of 4.0 percent defective. For lots over 1,300 pounds, 10 rivets shall be selected from each lot. The AQL shall be 2.5 percent defective.

4.4 Preparation of specimens.

4.4.1 Shear strength specimens. Rivet samples with a shank length 2-1/2 times the nominal diameter (and greater) shall be double or single shear tested as specified in 4.5.2.1. Rivet samples with a shank length less than 2-1/2 times the nominal diameter shall be single shear tested.

4.4.2 Heat Treatment of Tension test specimens. Tension test specimens shall be not less than 18 inches long (or 3 specimens not less than 6 inches long). The specimens shall be taken from the wire used to make the rivets and heat treated with the lot of rivets it represents.

4.4.3 Test after heat treatment. Specimens may be tested within 4 days after completion of the heat treatment. If, however, the specimens fail to conform to this specification, the test results may be discarded (except for 2219-T81) and the specimens retested after the expiration of 4 days without prejudice.

4.5 Inspection methods.

4.5.1 Examinations.

4.5.1.1 Visual inspection. The rivets shall be visually inspected to determine conformance to figure 1 and 3.8.

4.5.2 Tests.

4.5.2.1 Shear strength. The double shear strength tests shall be in accordance with MIL-STD-1312, Test 13 or ASTM-B565. The single shear test method shall be in accordance with MIL-STD-1312, Test 20.

4.5.2.2 Material tensile strength. The tensile strength test method shall be in accordance with ASTM E8, Test method 151.

4.5.2.3 Driveability. Using a proper driver, the rivet shall be driven in a sheet specimen of suitable thickness. The bucked rivet head shall be inspected for conformance to 3.9.

4.6 Inspection of Packaging. The sampling and inspection of the preservation, packing, and marking shall be examined and tested in accordance with PPP-H-1581 to determine conformance to section 5.

5. PACKAGING

5.1 Preservation. Preservation shall be Level A or C in accordance with PPP-H-1581.

5.2 Packing. Rivets shall be packed (Level A or C) in accordance with PPP-H-1581.

5.3 Marking.

5.3.1 Unit container labels. In addition to MIL-STD-129 marking, unit containers shall be marked with the special color-coded label identifying the alloy number.

Alloy	Color
1100	White
2017	Yellow
2024	Red
2117	Orange
2219	Violet
5056	Blue
7050	Green
45Cb	Grey

6. NOTES

6.1 Intended use. Rivets covered by this specification are intended for joining riveted structures that develop the driven load allowables defined in MIL-HDBK-5, Chapter 8.

6.1.1 Aluminum alloy 1100-F rivets are intended for use in low strength applications.

6.1.2 Aluminum alloy 2017-T4 rivets are high shear strength rivets intended for use with aluminum alloy sheets. This temper shall not be used where optimum corrosion resistance is required.

6.1.3 Aluminum alloy 2024-T4 rivets are high strength, high temperature rivets intended for use with aluminum alloy sheets.

6.1.4 Aluminum alloy 2117-T4 rivets are medium strength rivets intended for riveting aluminum alloy sheets.

6.1.5 Aluminum alloy 2219-T81 rivets are intended for use where high strength at a high temperature is required.

6.1.6 Aluminum alloy 5056-H32 rivets are intended for use with magnesium alloy structures and structures with magnesium and other alloys to minimize galvanic corrosion.

6.1.7 Aluminum alloy 7050-T73 rivets are high shear strength, high temperature rivets intended for use with aluminum alloy sheets. This alloy is intended as a substitute for alloy 2024-T4.

6.1.8 Titanium-columbium (45Cb) rivets are intended for riveting structures of titanium and aluminum or a combination of both. These rivets are intended to be used where material compatibility and cold formability are desired. They are suitable for use in high temperature and high strength applications.

6.2 Ordering data. Procurement documents should specify:

(a) Title, number, and date of this specification.
(b) MS part number, material condition and composition. (See 1.2).
(c) Level of packaging required (see 5.1).

Custodians:
Army - AV
Navy - AS
Air Force - 11

Reviewer activities:
Army - AR
Air Force - 99
DLA-IS

Preparing activity:
Navy - AS

Project No. 5320-0320